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CONTENTS.

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PAGE

Portrait of the President (Sir George Lee, O.B.E., M.C.) .... *Frontispiece*

Inaugural Address .... Sir George Lee, O.B.E, M.C. 1

Wireless Section: Chairman's Address .... T. Wadsworth, M.Sc. 10

Meter and Instrument Section: Chairman's Address .... H. Cobden Turner 20

Transmission Section: Chairman's Address .... J. L. Eve 26

Addresses of Chairmen of Local Centres:

- **Western** .... H. G. Weaver 30
- **North Midland** .... J. G. Craven 34
- **Scottish** .... Major H. Bell, O.B.E, T.D. 39
- **Mersey and North Wales (Liverpool)** .... G. K. Paton 44
- **North-Western** .... J. W. Thomas, B.Sc.Tech., LL.B. 49
- **South Midland** .... H. Hooper 55
- **North-Eastern** .... W. D. Horsley 61
- **Irish** .... Lieut.-Col. K. E. Edgeworth, D.S.O., M.C. 67

Addresses of Chairmen of Local Sub-Centres:

- **East Midland** .... D. H. Parry, B.Sc. 73
- **Tees-Side** .... J. H. Haws 78
- **Hampshire** .... W. F. Rawlinson, D.Sc. 84
- **Dundee** .... A. Grant, B.Sc. 88
- **Sheffield** .... W. F. C. Cooper, B.Sc.(Eng.) 94
- **Northern Ireland** .... F. H. Whysall 98

An Electrical Method of determining Cable-Sheath Uniformity .... W. E. Laycock 101

Theory and Performance of the Iconoscope.
V. K. Zworykin, Ph.D., G. A. Morton, Ph.D., and L. E. Flory 105

Proceedings of The Institution 114

Institution Notes 116

Advertisements .... At end i–xviii

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[*Continued on page (III) of Cover.*

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INAUGURAL ADDRESS

By SIR GEORGE LEE, O.B.E., M.C., President.

(*Address delivered before* THE INSTITUTION 21*st October*, 1937.)

I should like first to convey to the members of The Institution my sincere appreciation of the honour they have done me in electing me as President for the current session. Fortunately the tasks involved do not fall upon the President alone; he is helped and advised by a Council and its Committees, long-experienced and skilled in the art, and by a secretariat whose efficiency has stood the test of many years of service. I can only say that I shall do my utmost to uphold the high traditions of the office and to endeavour to push forward all the interests and activities of The Institution and its members. I am particularly looking forward to the opportunities which are associated with the duties of President—of making contacts with the Local Centres and with those members of The Institution who are too far from London to attend the main meetings. It is always more effort to keep the interest and enthusiasm in a live state when the members are scattered far and wide and find difficulty in attending meetings. The Local Centres therefore perform a most valuable work in enabling meetings to be held in some of our largest towns where groups of electrical engineers of various kinds can meet and discuss the new developments which arise so quickly in the electrical industry.

I think that the rapidity of development of electrical engineering in its technical phases has not been equalled in any other branch of engineering, and we can attribute this very largely to the propagation of knowledge by The Institution. Every new advance is built upon the foundations of some previous work, and it is therefore incumbent upon all of us to record for the benefit of our fellow workers the steps on the road of technical progress. In this we are following the tradition set by some of the earlier scientific institutions in this country, the unselfish sharing of knowledge.

The modern trend in The Institution is to split off gradually, amoeba fashion, into separate sections of specialists, such as the Wireless, Transmission, and Meter and Instrument Sections, where concentrated discussions on these subjects can take place. It is proposed to form others when the need arises, but they will still remain integral parts of The Institution. We may, perhaps, look forward to a state in the future when The Institution will consist entirely of such Sections.

It would be rather interesting to reflect upon what would have happened if the parent engineering Institution in this country, The Institution of Civil Engineers, had adopted a similar policy in past years. Whatever advantages or disadvantages we may see in the separation which has grown up in the engineering profession, and which it is now too late to remedy, we can, I think, all agree that a closer connection between the different engineering Institutions would be of lasting benefit to the profession of engineering. The President of The Institution of Civil Engineers last year, Sir Alexander Gibb, in his presidential address set forth a plea for closer co-operation and co-ordination between the different branches of engineering. I should like to see this question examined sympathetically and carefully in order to ascertain what are the possibilities. I think we have to rule out actual cohesion between the various Institutions, because the industry is now too large and too varied, but if we ask ourselves in what directions co-operation would be useful, I think we could put forward at least two main possibilities, and others would, no doubt, develop in due course.

(*a*) An improvement in the methods of distributing and sharing knowledge, in which might be included facilities for members attending meetings of other Institutions, joint meetings on subjects of common interest, joint use of library facilities, etc.

(*b*) The closer association and meeting of people who are interested in different phases of what is actually the same subject would facilitate the recognition of common interests and ideas. To an increasing extent the lives of our people are bound up with engineering development, and the economics of our welfare are dependent to a large extent upon the rate of this development. The full implications of social science can best be handled from the engineering side by the combined efforts of all the engineering professions.

I should like, therefore, to re-echo Sir Alexander Gibb's suggestion that we should subordinate some of our more personal and independent views and feelings to a common policy, and that we should examine the possibilities of co-operation in a mutually helpful spirit.

It is customary for the presidential address to be devoted, in part, to a review of some of the engineering activities with which this Institution is concerned, and I think I cannot do better than to talk about the activities with which I am most familiar, those of the Government Department in which I serve.

TELEPHONE TARIFFS

We have for many years past devoted our attention to reducing the costs of telephone service as a prelude to the actual reduction of tariff rates. In October, 1934, with the turning of the commercial tide in this country, we were able to offer very much reduced tariff rates, and the public response to these and subsequent cuts has been such that the growth of the system has been phenomenal. I should therefore like to describe what we have done, and are doing for the future, to meet the situation.

I spoke of the past, in which efforts to reduce costs were made, in which we were ably assisted by the manufacturers in the telephone industry. This was accompanied by very important technical improvements in the quality of service. We now have the opportunity of applying still further technical improvements designed to reduce costs and increase quality. The growth induced by the tariff cuts enables us to apply the improvements immediately in new plant, without waiting for obsolescence and depreciation to perform their normal functions in the accounts of the business. When sufficient new and cheaper plant has been installed, so as to bring down the average cost, there will come the opportunity for still further tariff cuts and more growth.

This process looks like being a continuing one, until costs can be reduced no further or we reach saturation; but saturation is a long way off, and before that arrives I anticipate that the march of invention will bring new possibilities for exploitation which will absorb our energies for very many years to come.

The standard two-part residential tariff, applicable everywhere except in the largest towns and some of the mountain tops in England, Wales, and Scotland, is now reduced to £4 and a penny per call (with 200 free calls per annum); the day trunk rate now has a maximum of 2s. 6d. for the longest distances and 1s. after 7 p.m., with other cuts for shorter distances. The 1s. night-rate was a very successful psychological touch, which has succeeded beyond our wildest expectations, from the point of view both of service to the public and also of revenue, as it gives a better load factor.

Some idea of the effect of these tariff cuts can be gained from the following figures:—

Net Annual Increase in Total Telephones

1931/2	1932/3	1933/4	1934/5	1935/6	1936/7
72 862	68 509	87 906	162 802	191 204	247 983

Total Trunk Calls

Half year ending March, 1935	39 582 000
Half year ending September, 1935	44 189 000
Half year ending March, 1936	44 097 000
Half year ending September, 1936	49 358 000
Half year ending March, 1937	49 606 000

These increases have been accompanied by an increase in the calling rate. The spare plant with which we started the tariff cuts has rapidly become exhausted and considerable new construction work has become necessary. Working circuits from London to the middle-North and to the South-West, and between London and Scotland, have been tripled in number since 1934. This has led to a large increase of personnel, both in the Department and in the manufacturers' works.

The expansion of the local underground cable network, the conversion of manual exchanges to the automatic system, and the growth of the trunk system, do not present any specially new problems except for the magnitude of the operations and the organization required to meet them. New methods have, however, been evolved to expedite the provision for this rapid growth. The subject of forecasting development has been improved in the direction of reliability. New methods of maintenance have also been developed, tending to reduce costs and ensure more reliable service.

TRAINING OF PERSONNEL

Expansion of labour-forces involves the training of non-skilled personnel, and it has been necessary to enlarge considerably our previously existing school and other training schemes.

The rate of increase of the workmen grades has, for some time past, been over 6 000 per annum. We have a central school at Dollis Hill, which is used for imparting instruction in the more specialized forms of new plant, and we now have, in addition, regional schools in some of the larger towns in the provinces, where the equipment of the school is of a simpler character. The number of trainees yearly passing through the central school is now 4 500, there being accommodation for 600 students at the same time. The regional schools have accommodation in all for approximately 800 students. It is interesting to notice the speed with which modern youth adapts itself to the maintenance of the most complex of automatic exchanges and high-frequency transmission systems. High-speed and expert teaching is a necessary part of the process, and the old days when a newcomer was placed in the care of a skilled workman to learn his job are gone. He is allowed to gain experience by that method, but he should learn first of all how to do the work correctly, without the possibility of acquiring wrong methods from older men.

Training is a practical problem which arises in every industry. Looked at from the wider standpoint of the economic state of the country at any moment, we have industries on the decline and other industries fortunately on the upward grade. During these natural economic fluctuations, labour has to transfer from one industry to another and, in order that it may do this and live during the operation, reasonable pay conditions must obtain during the training period. It is in the best interests of labour and the industries concerned that the training shall be conducted in the most efficient and economical way. We are fortunately a large enough industry to conduct training on a sufficient scale and as efficiently as we know how. To summarize very briefly, our present methods consist of a school training coupled with subsequent experience in the field. Education of the workmen—a matter distinct from vocational training—is provided for by the technical colleges and schools, supplemented by correspondence courses run by the central school at Dollis Hill for workmen who are stationed too far from centres of population where technical education can be obtained. We have 4 000 such students taking the correspondence courses.

DEVELOPMENT FORECASTING

Before plant is laid down, it is desirable that we should know how much will be required over a period of years and where it will be wanted. We do not lay cables with one pair of wires at a time—some of them contain hundreds of pairs—and exchanges are constructed for several thousands of subscribers. In order to reduce line costs to a minimum the exchange should be at the economic centre of the area. Knowledge of the incidence of growth is therefore of prime importance for economic layout.

The processes of calculation have already been described in a paper read before this Institution.*

The new methods of development-forecasting are based upon an expansion of market-research methods. The growth of telephones is related to the tariffs, the general economic state of the country, the economic state of the particular town, and the economic position of the potential subscribers, coupled with some estimate of the changes in these factors with time. Long-term planning requires forecasts of what will happen in the next 20 years, but we cannot do more than guess for so far ahead, and revision of the forecasts is therefore carried out every 5 years. A guess based upon the most carefully tabulated information and judgment is more likely to be near the mark than one made without due care and study.

The demand on capital for the provision of new plant is very vitally affected by accurate development-forecasting; and as capital charges, in the form of interest and depreciation, comprise such a large part of telephone costs, it is essential that this work should be well done if future costs are to be kept low. Under-forecasting is just as wasteful as over-forecasting.

It is very difficult to include in our forecasting the effects of research and engineering developments. These may be of two kinds, reduction in cost or improvement in service, both of which are attractions in the direction of increasing either the number of new subscribers or the use made of the service. Sometimes the information available is only such as to enable us to give a bias to a particular set of figures, but we can count on a supply of new developments coming on at more or less regular intervals, and those developments will have the effect of stimulating growth in various directions. In general, then, we are liable to under-forecasting owing to this cause, but this under-forecasting may possibly counterbalance some unforeseen slump in the future, and in any case under-forecasting accompanied by reduced costs is not so bad as under-forecasting without any compensations.

TRENDS OF TELEPHONE COMMUNICATION DESIGN

The natural separation of a telephone undertaking into three separate groups of work:—

(*a*) Local exchanges and their network,
(*b*) Trunk system (national),
(*c*) Trunk system (international),

is based partly on the system of *tarification* and partly on the distinct nature of the technical problems presented.

In (*a*), the local exchange and its network, we have decided on a complete policy of mechanization on the Strowger system. At the present time we have 50 per cent of our telephones on the automatic system, and further transfers from manual to automatic are proceeding rapidly. The main problems at the moment are the provision of new plant in large quantities and the improvement of maintenance and service conditions. I propose to say something on the maintenance aspect later in this Address. I foresee, however, that the emphasis which is being laid on this will lead to the development of new systems in which reliability of service will be very much improved.

In (*b*), the national trunk system, we have very rapid provision to cater for, and, in addition, it is desired to improve the technical quality of underground trunk circuits. At present, 90 per cent of our trunk circuits are underground, where they enjoy a degree of immunity from faults which is very much better than on open-wire circuits.

The loading of underground circuits with inductances to reduce the attenuation was first commenced just over 30 years ago. The amplifier, or repeater, came about the War period and reduced the necessity for so much loading. Now, with the arrival of the feed-back repeater, we have the economic possibility of carrier on underground circuits, and, for short distances, unloaded circuits with feed-back amplifiers. Loading is therefore being replaced in the newer cables by unloaded circuits. The new trend entails a large number of problems in signalling (calling, dialling, and clearing), as well as in the complexities of amplifiers and filter arrangements.

On the operating side the trend is towards mechanization, which is expected to lead to a quicker and cheaper system.

In (*c*), the international trunk system, work on the organization and technical processes is proceeding steadily. The main problems are similar in character to the national trunking problems except for the magnitude of the distances involved, and in some cases the introduction of radio links. The general present-day solutions of carrier and mechanization will probably be applicable in this field.

PROVISION OF TRUNK CIRCUITS, CARRIER, TELEVISION, ETC.

I now wish to refer to the use which is being made of high-frequency transmission in planning the provision of the large numbers of trunk circuits in the longer distances that are being called for to meet the continual growth in traffic. The original main line of development in the application of the carrier principle was in the multiple use of open-wire lines, systems affording up to three extra channels being in use. It is largely the realization, in practical form, of the negative feed-back repeater by Black* that has made possible the recent advances in carrier on cables. Technical descriptions of experimental 12-channel and coaxial installations have been given in a paper recently presented before this Institution.†

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* J. G. Hines: *Journal I.E.E.*, 1929, vol. 6, p. 594.

* H. S. Black: *Electrical Engineering*, 1934, vol. 53, p. 114.

† A. S. Angwin and R. A. Mack: *Journal I.E.E.*, 1937, vol. 81, p. 573.

*

The so-called 12-channel system, which carries 12 telephone conversations on each physical circuit, operates over underground cable pairs and employs a frequency range extending to 60 kc. This does not represent so great a break with earlier technique as the coaxial system, which uses lines of special construction and frequencies extending into the megacycle range. The 12-channel system has emerged from the experimental stage, though, no doubt, it is not yet in its final form. Prior to the changes in tariffs in 1934, the blocks of 12 potential circuits represented by each pair would have been too large on all except a few routes, but groups of this size are well adapted to present requirements of traffic on the longer routes. The adoption of the 12-channel system as standard for new circuits between zone centres, besides materially reducing the cost of new circuits, has eased the pressure on cable manufacturers. Cables provided on a 12-channel basis contain roughly one-sixth of the material in the equivalent audio cables operated in accordance with the prior technique. The layout of equipment at all strategic points on the 12-channel network which is being built up, is being arranged to give in the routing of circuits the greatest amount of flexibility that is compatible with the avoidance of cross-talk. This feature will be of great value in enabling the maximum use of plant to be obtained, by providing circuits by alternative routings in the event of unexpected traffic demands and in cases of breakdown.

Reduction in expenditure on cables by 12-channel working is accompanied by a heavy increase in equipment at the terminals, and its accommodation is proving a matter of considerable difficulty. In the 12-channel system, repeater stations are required at intervals of about 20 miles.

In the past, when growth was smaller and such trunk cables as were laid sufficed for a longer period of time, it was more practicable to design each cable to suit the expected traffic for a carefully-calculated economic period. In the 12-channel system the initial outlay on cable provision is relatively small and the cost of equipment can be incurred as and when increase in traffic requires it.

It would have been possible to have combined pairs for 12-channel working with pairs for short-distance audio circuits in the same cables, but the decision to proceed with the provision of a separate network linking the zone centres has enabled a standardized cable to be employed, with consequent manufacturing advantages, and with increase in speed and simplicity of planning which, in present circumstances at any rate, amply justify the course taken.

A further carrier system which is under trial is that of wide frequency-band carrier on the coaxial cable. The coaxial system is capable of providing large blocks of circuits over long distances at a low cost, but traffic in this country has not reached an intensity which would make the handling of traffic in such large blocks generally appropriate. We are, however, proceeding with the provision of coaxial cable on what may be regarded as the main artery of trunk telephone traffic—from London to Birmingham, Manchester, Leeds, Newcastle, and, possibly at a later stage, to Edinburgh and Glasgow. There are still many problems of design and manufacture which will, without doubt, be vastly improved. I look forward to a time when research and development of manufacturing technique will have made wide-band systems, such as the coaxial, an economic method of circuit provision for relatively short circuits of 20 or 30 miles.

Besides its use for telephony, however, the installation of the coaxial cable was undertaken with a view to making provision for the transmission of television programmes.

The pressing need for telephone circuits on the route of the cable has led to the development work for television transmission being delayed, but it is the intention to concentrate more effort on this aspect. The technical problems involved in the transmission of television signals over land lines for long distances are very difficult, but the popularizing of television will inevitably, I think, lead to the linking together by land lines of all the main centres of the country. I would even go further and suggest that distribution of television programmes by wire to subscribers may well be the means of so simplifying and cheapening the cost of television-broadcast reception as finally to make entertainment by television in the home as widespread as sound-broadcast reception is to-day.

TRUNK SERVICE—MECHANIZATION

The experience so far gained with the local automatic exchange system is that it is quicker and more reliable than manual operation. When connections have to be set up in tandem the delays in manual operation tend to increase more seriously, owing to the necessity for finding a free operator and a free line at each point. On the other hand, automatic operation, as the price for its speed, demands a more liberal provision of lines to give a no-delay service, as it cannot conveniently store calls to take their turn one after the other. In addition, the signalling (dialling, calling, and clearing) in short-distance working can be performed by direct current, while for the longer trunks, the amplifiers on which cannot handle direct current, some method of voice-frequency signalling, which is not operated by the speech currents themselves, is necessary. We have developed a voice-frequency signalling system using two frequencies, 600 and 750 cycles per sec., the receiving arrangement being tuned to respond to the comparatively pure wave-form of the signalling impulses and not to the complex wide band of frequencies present in speech transmission. The more liberal provision of circuits becomes possible through the introduction of carrier working, which enables more circuits to be provided on an economical basis.

The first step which is being taken is to apply the voice-frequency signalling system to our existing manual trunk network. This will enable the controlling operator at the originating trunk exchange to dial the subscriber direct in all towns to which she has a through trunk connection, without the intervention of the operator in the distant town. Later, when the circuit provision is ready, we hope to have automatic switches available which will enable trunk circuits to be set up in tandem and subscribers in any town dialled direct by the controlling trunk operator. This process will take some time to install and we may not, perhaps, find it economical to extend the system to the smallest places. That is, however, a matter for the future. It will probably always be necessary to have one controlling trunk operator in the chain to set up the circuit and make out the ticket with the appropriate charges for the call, though in the smaller areas, for calls up to 15 miles, we contemplate that subscribers will be able to dial direct to the different towns by code dialling, and meters have been designed to record the charges automatically. Code dialling, however, applied to several thousand towns in the whole country, would be too complex for the ordinary subscriber to handle.

With the more liberal provision of circuits having zero attenuation, together with mechanization, we hope ultimately to achieve the ideal of a trunk service which is as speedy in connection and as comfortable to talk over as the local service is at present, and which shall be truly independent of locality or distance.

INTERNATIONAL TELEPHONY

Very shortly after the World War an International Consultative Committee on Telephony, known by the initials C.C.I.F., was set up in order to co-ordinate the efforts of the various administrations concerned with telephone matters. This committee was, to a large extent, the outcome of the suggestions contained in the Presidential Address of Mr. F. Gill.* It has done very great work during its existence and has, further, given rise to committees of a similar nature dealing with telegraphy and radio work. The American Telephone and Telegraph Co. and the International Telephone and Telegraph Co. are represented on the C.C.I.F., and the engineers of those organizations have put all their technical data and experience at the disposal of the committee.

One of the fundamental purposes of this committee is the setting up of specifications which should enable international telephony to be carried on efficiently in spite of constructional differences in the various countries. The work has been tackled whole-heartedly by the administrations concerned, and also by the various concessionaire and manufacturing companies in the different countries. Co-ordination and co-operation have produced very marked results. It is not too much to say that without this committee European telephone communications could never have advanced to their present stage in the time. Perhaps the most difficult problem of all is now being studied by a special subcommission of the committee, namely the fundamental European layout plan. In order to ensure that communication between any two points in Europe shall be both effective and satisfactory, it is essential to plan carefully and with foresight. Up to the present, each country has planned largely on the basis of its own economic requirements, together with consideration for the long-distance services which each carried across its terrain.

In order to evolve a satisfactory plan it is necessary to study several fundamental points, first, the necessary volume of transmission, which, as a minimum, is requisite between any two subscribers, and second, the intelligibility of the conversation. For some years past the advances in technique in the production of cables and amplifying equipment have ensured that sufficient volume for commercial speech can be given between any two subscribers on the Continent. The matter of intelligibility, however, raises a number of questions, some of which are very difficult of solution. The first matter which affects intelligibility is the frequency band required for intelligible speech. This has been fixed tentatively at between 300 and 2 700 cycles per sec. There is, however, a tendency to elongate this band in both directions, especially now that telephone instruments are reaching a much greater pitch of perfection. It is probable that within the next few years the band width will be increased so as to embrace all frequencies between 150 and 3 200 cycles per sec.

The next point that arises is the distortion which takes place during transmission, owing to a variety of causes. If all frequencies could be transmitted with the same efficiency and at the same speed, distortion could be considered to be negligible. There is, however, always present in addition some degree of what is termed "non-linear" distortion, due to the production of harmonics by iron losses in loading-coils and transformers and by the non-linear characteristics of amplifying valves. The C.C.I.F. has issued specifications which require the amount of distortion to be kept within certain bounds.

A further source of distortion arises from the production of echo currents which are propagated by reflections from discontinuities in a circuit or from bad impedance-matching at the terminal. It is beyond the scope of these remarks to discuss the reason why these echoes are produced; it merely suffices to take the practical issue that they do exist and can become a very serious detriment to the intelligibility of speech. During last year engineers of Great Britain, Germany, and France, have been making a number of tests in order to determine the extent to which these echo effects may account for loss of intelligibility, and their relative importance in long-distance transmission. There is, of course, an instrument in use which has for its chief function the abolition of all echo currents. This, however, has the effect of rendering a conversation temporarily unidirectional. It is quite possible that room noise, etc., might operate this device and prevent a listening subscriber from hearing the speech from the distant end. An echo suppressor is therefore so regulated that there is little danger of this ever happening. Under these conditions, faint sounds do not operate the suppressor and so may give rise to faint echoes tending to produce distortion. This factor tends to limit the volume efficiency which a long-distance circuit can attain. The results of the tests, so far, indicate that the weak echo will not prevent long-distance circuits in Europe being worked in such a manner that the transmission loss over the circuit is practically negligible. The importance of this fact can hardly be over-estimated, since the economics of a telephone network depend largely on the expenditure in distribution to subscribers in the big towns. At present a certain proportion of the permissible loss has to be allowed for the attenuation on the main trunk lines. If this attenuation loss can be reduced to zero, as is already done in this country, the amount of copper which it is necessary to use in distributing from the trunk system to the subscriber may be smaller. Fundamentally, if any two towns can be connected together with a negligible transmission loss, the maximum savings in line cost over the whole system can be achieved. If agreement be reached by the C.C.I.F. to operate the international system on these lines, there is no question that a very big step forward will have been taken.

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* *Journal I.E.E.* 1922, vol. 61, p. 1.

In this country it has been decided recently that, taking into account both national and international telephony, it is necessary to design circuits in such a way that the speed of transmission is as large as possible. When the distance to be traversed is great, it may be that the spoken word reaches the far end at a noticeable interval of time behind the originating sound. It has been found that $\frac{1}{4}$ second is the maximum time which can be allowed for transmission, without introducing difficulties in communication. Modern circuits are therefore being designed for higher speeds of transmission.

Another factor to be decided in a European layout plan is the question of noise. This problem is giving many engineers most serious food for thought. Noise can be introduced in telephone circuits from power interference and similar causes, and when so introduced is very difficult to eliminate. The type of noise has a great deal of influence on the effect produced on the listener. Further, the extent to which intelligibility is lost owing to two noises of a different nature has not necessarily any direct relation to the total amount of noise. Experiments are being carried out in this and other countries to determine the extent to which noise can be tolerated and to classify both the noises and their effects on the telephone system. Co-operation between telephone and power engineers is afforded through an international mixed commission which co-operates with delegates of the C.C.I.F. It is most pleasing to notice that with the co-operation and friendly spirit in which these problems are discussed and solved, engineers of the telephone and power interests can, in fact, show the world a great lesson as to how difficulties and troubles can be overcome.

Finally, there is a further problem of the better utilization of lines by the introduction of automatic switching. Largely on account of language difficulties the present European plan is based upon separate groups of lines between each of the important communication centres in Europe. Such groups are necessarily small and cannot be worked as efficiently as large groups of circuits, the chance of a circuit being free for an additional call being much greater in a large group than in a small one. It has been suggested that the introduction of automatic switching would remove the language difficulty and enable large groups of circuits to be handled by automatic switches at the important centres.

MAINTENANCE

The maintenance of the communication system is closely allied to its development, and it will be appreciated that the design and construction of the plant have a profound effect, not only on the subsequent maintenance effort but on the service results. I am not going into these features of the problem at length except, perhaps, to say that a little extra cost in design, engineering, construction, or installation, in many cases pays its way in lessening maintenance effort or service reactions.

As it is largely by experience that improvements can take place, one of the most important duties of the maintenance engineer is to search for the weak spots of the system with which he is concerned, with a view to arranging for improvements in future equipment.

An automatic telephone system consists essentially of a large number of selecting mechanisms (known as selectors) and electromagnetic relays, and efforts have naturally been directed to the development of improvements in the selector design and to obtaining a relay with the maximum reliability in operation and freedom from contact failure.

After much investigation and research the present standard 3 000-type relay was developed in conjunction with our contractors. Subsequent field trials showed its marked superiority to any other existing telephone relay, and it was therefore standardized in 1934. Fig. 1 (see Plate, facing page 6) shows the new type of relay. The most important features of this relay are:—

(*a*) High magnetic efficiency,
(*b*) Twin contacts,
(*c*) Use of silver for contacting,
(*d*) Use of buffer block to ensure adequate spring contact pressure and clearance, and to simplify adjustment.

The following comparison of the average fault liability under working conditions of the new standard relay and the other types of telephone relay in service may be of interest.

	New standard relay	Other types of telephone relays
Faults per relay per annum . .	0·025	0·100

The importance of the correct operation of relays in a telephone system will be appreciated when it is stated that there may be as many as 100 000 in a telephone exchange of the director type, as in London; whilst the setting up of a single call may involve upwards of 200 relays and 1 500 contact operations. There are $1\frac{1}{2}$ million of the 3 000 type in service, out of a total of 17 million relays.

We have recently standardized a new design of selector mechanism, developed by one of the manufacturers in this country, which is known as the 2 000-type selector. Fig. 2 (see Plate) illustrates this selector, and the following are a few of its advantages:—

(*a*) Greater magnetic efficiency,
(*b*) Improved design and mounting of mechanically-operated springs,
(*c*) Ease of removal and replacement from bank,
(*d*) Reduced overall dimensions,
(*e*) Greater bank capacity,
(*f*) Greater ease of adjustment,
(*g*) Reduced cost,
(*h*) Uniformity in design of components.

All future exchanges will be provided with this improved design of equipment, and, from experience at the few exchanges already having this selector in service,

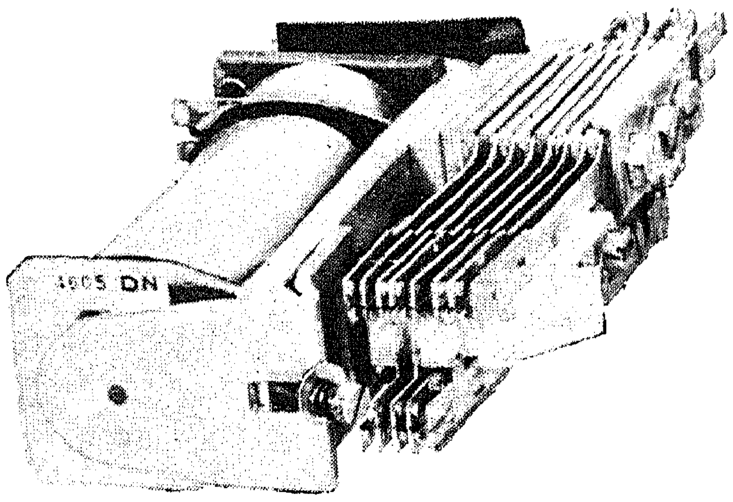
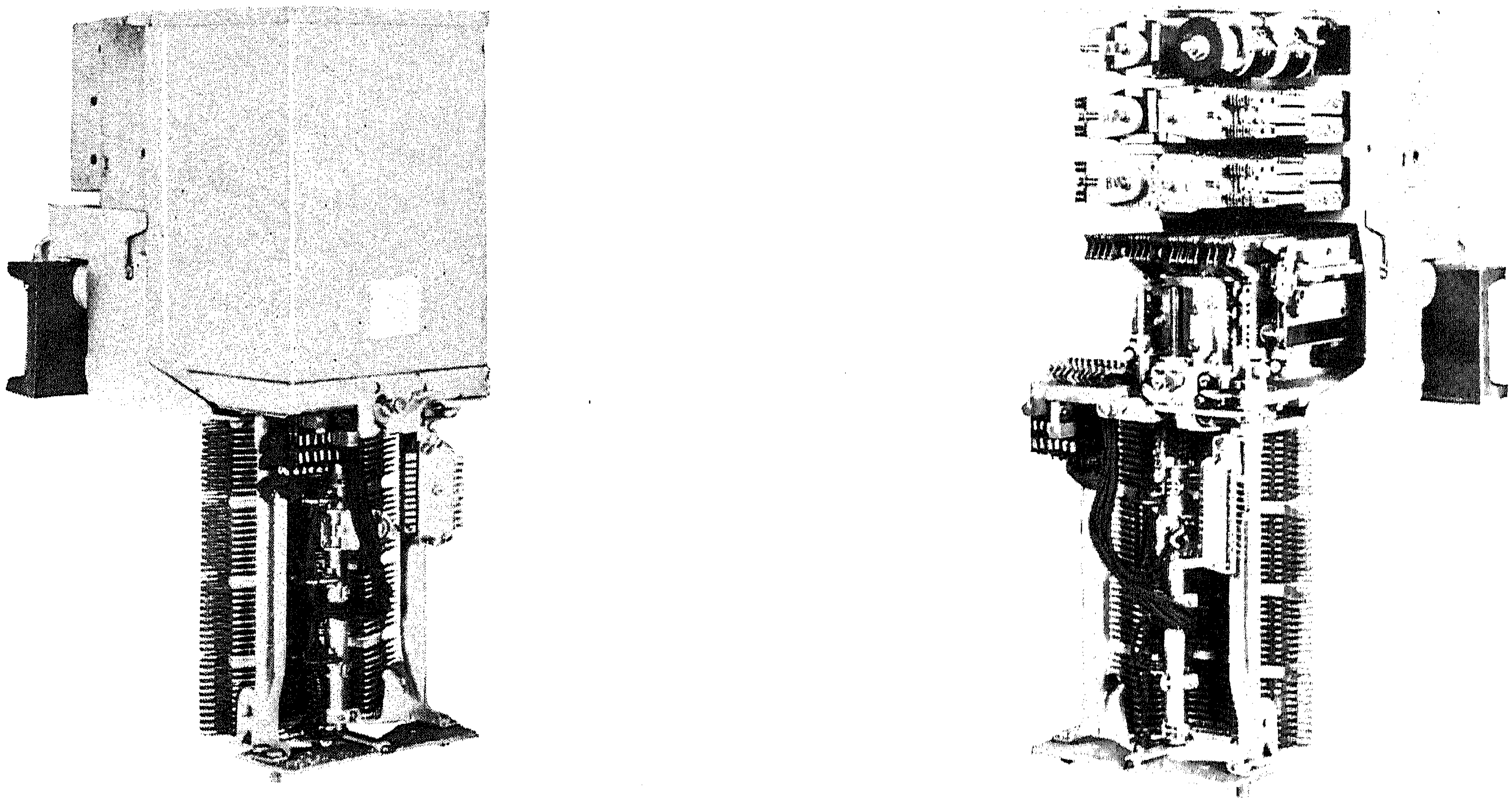


Fig. 1.—Standard relay (3 000 type).



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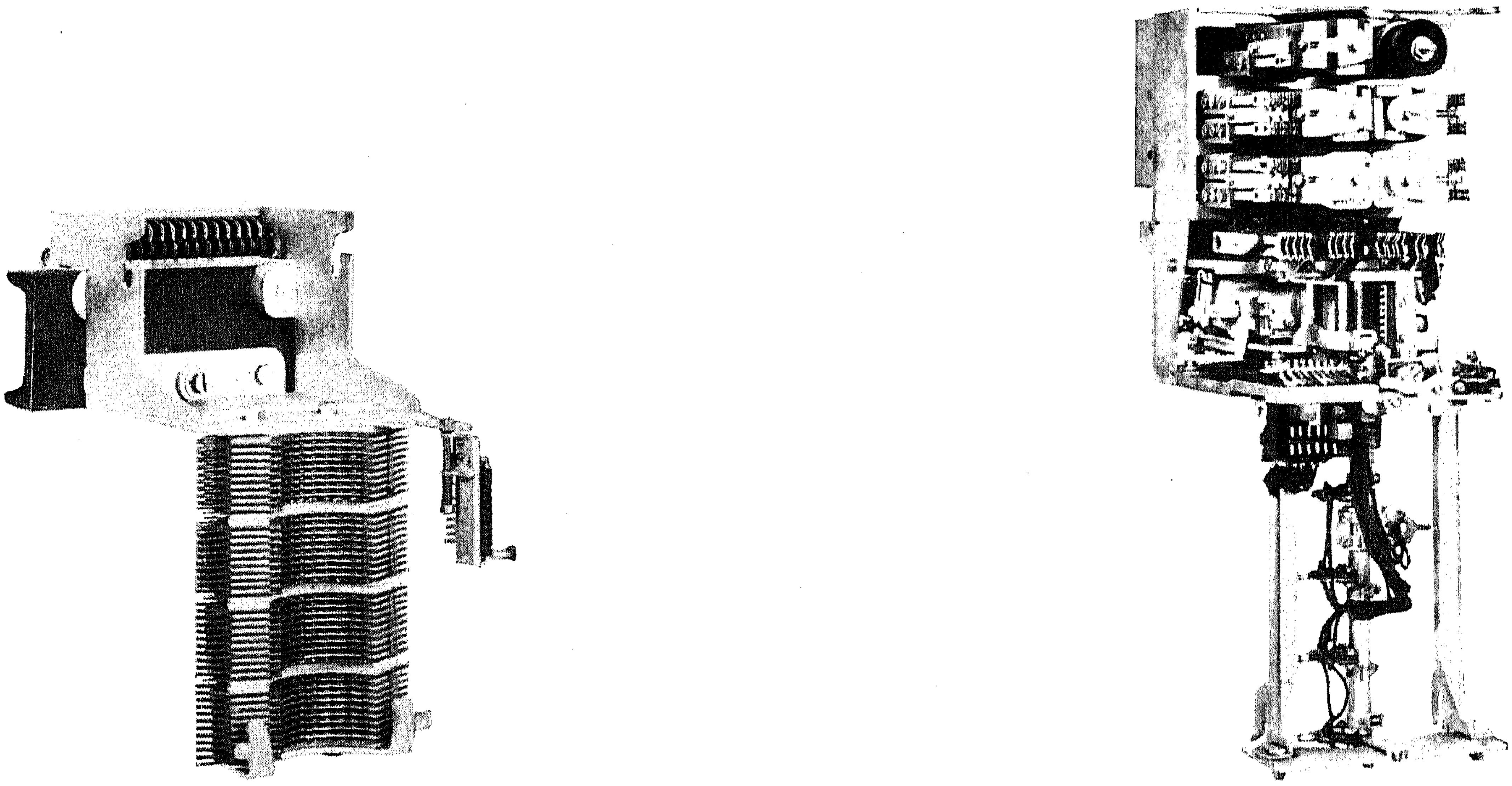


Banks.

Selector detached from banks.

Fig. 2.—Standard selector (2 000 type).

the indications are that the anticipated improvement in performance will be achieved.

In the case of external line plant the replacement of overhead routes by underground cables has been a further step towards reducing maintenance costs and increasing the reliability of the plant.

The instances given are typical of developments constantly being made in switching and telephone equipment to improve the efficiency and reduce the cost of the telecommunication service.

The basis of maintenance, from a service point of view, is first to aim at the prevention of faults, and secondly to find such faults as do occur before they affect the subscribers' service. Our maintenance is based largely on routine inspections, overhauls, and testing. These inspections and overhauls are carried out at regular periods. The inspections are designed to confirm that plant is in a satisfactory condition; the overhauls are carried out periodically to readjust portions of the plant, the performance of which tends to alter in the course of time, and to renew parts which are affected by wear and tear. Routine testing is carried out frequently in order to test, step by step, the operation of the complicated circuits and apparatus involved in automatic exchange equipment, with a view to locating faults before they affect service.

In this connection, the use of testing equipment which is completely automatic in operation, known as an "automatic routiner," may be mentioned. These routiners, which consist mainly of relays and single-motion selectors, are applied to the plant to be tested by means of access switches. They test in turn for all the various fault conditions the whole of the items in the group of equipment concerned, and, should a fault be found, the testing is automatically stopped and the particular item of plant concerned, together with the nature of the fault, is indicted on a lamp display. It will be realized that for testing such items as selectors, of which there may be 7 000 or 8 000 in a large exchange, these routiners effect considerable economy as compared with any manual means of testing such large blocks of equipment.

The ultimate aim of a telephone connection is of course successful conversation, and arrangements have recently been made to introduce a test by which the speaking efficiency of the subscriber's telephone can be indicated visibly on an instrument at the exchange desk. Whenever a faultsman visits the subscriber's telephone he will confirm the performance of the instrument before he leaves it by applying to the transmitter an instrument which is a sound generator, and emits a known volume of sound. By this means the exchange testing officer is enabled to measure the received sound and thus check the transmission efficiency of the telephone. In addition a periodical test of the exchange plant also ensures that the transmission loss of the exchange equipment is not excessive.

Apart from the liability to individual faults, the nature of the telephone system is such that it is subject to breakdowns of a much greater magnitude. For instance, a cable breakdown will affect a large number of circuits. To reduce the possibility of such an event occurring without warning, periodical tests are made of the insulation resistance of all junction and trunk circuits throughout the network. These tests have hitherto been made by a bridge megger, but in order to save time a routiner has now been developed which automatically tests the insulation resistance of the circuits one after another, an alarm being given whenever a circuit with an insulation resistance lower than normal is found. The tests with this equipment are made at such intervals that the insulation resistance is unlikely to obtain an unduly low value before its discovery, and remedial action can thus be taken before a fault having a widespread effect on the service develops.

Details of all faults are recorded statistically, so that a periodic analysis can be made to indicate the main source of troubles. Depending upon the nature of the faults, the inspections, overhauls, and frequency of routining are adjusted with a view to building up a maintenance organization which will prevent faults actually arising in service, and at the same time perform these operations with the maximum economy. Records are maintained of faults and maintenance costs on the various types of apparatus, and the statistical presentation is such that control can be effected both locally and at headquarters. It will be realized that centralized control of a fairly complex character is necessary in a system in which the plant units are distributed in every town in the country. Fig. 3 is a graph showing the reduction in maintenance costs since 1927. In 1927 the exchange plant was nearly 100 % of the manual type, and in 1937 50 % is automatic. The reduction in cost has been attained in spite of the growth of the more complex automatic plant.

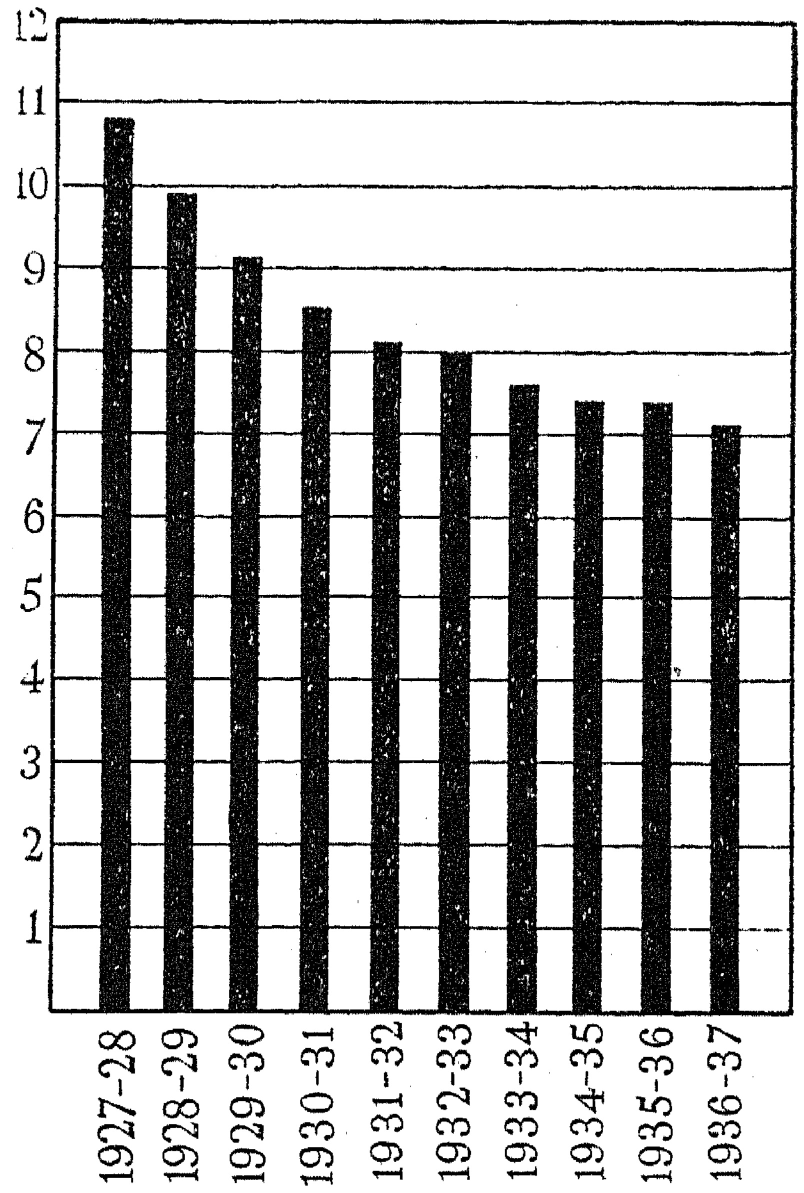


Fig. 3.—Maintenance of telephone system (man-hours per plant unit per annum).

TELEGRAPHY

Line telegraphy has, perhaps, to some extent been overshadowed in recent years by the spectacular achievements in line telephony and radio communication. Nevertheless, here, as elsewhere in the field of telecommunication engineering, unceasing effort has been directed towards obtaining all possible economies and improvements in the service. Within the past decade wholesale changes in equipment and technical practices have effected a complete metamorphosis in the operation of the telegraphs.

There is a very important difference between the economics of telegraph and telephone services, in that the operating charges preponderate very considerably over all other charges in the case of telegraphs. The prime consideration in reducing the cost of telegraph service must therefore be one of providing the maximum facilities, and the most efficient means for handling and signalling the telegrams. In directing development towards this end, one of the objects has naturally been to secure a system of telegraph-working which places the least possible demands on the telegraphist and permits a high average output to be secured without difficulty. Up to date the best method known of achieving this end is by use of the teleprinter, a relatively simple self-contained keyboard-operated typewriting instrument which can be worked direct to line without the intervention of any subsidiary perforating or multiplexing equipment. The policy was therefore adopted of abolishing from the inland service all the older systems of telegraphy, and the whole of the heavily worked circuits have now been converted to teleprinter operation, while the very lightly loaded circuits have been converted to telephone working.

A more recent development has been the introduction of an "ancillary" system of teleprinter working to facilitate operating on medium-loaded circuits. In this system, at each operating position, a small switchboard is provided, by means of which calls may be received from, or originated to, any one of a group of teleprinter offices. In addition, "answer back" units have been fitted to the teleprinter, whereby a sending operator may, after signalling a message, cause the teleprinter at the distant office to transmit back automatically the code letters for that office. Correct receipt of this code can be taken to confirm that the telegram has been duly received at the proper office, and the connection may then be released without awaiting the attention of an operator. The combined effect of all the steps taken has been to secure a 65 % improvement in the average hourly output, compared with that obtaining before the introduction of teleprinters.

In addition, the transit of telegrams inside the offices from circuit to circuit, and from circuit to output, has been speeded up and facilitated by ample provision of conveyor belts.

Sweeping as the changes in instrument-room practice have been, even more radical has been the reorganization which has taken place in the line network.

The multi-channel voice-frequency telegraph system, which enables 18 duplex telegraph channels to be worked simultaneously on a 4-wire telephone circuit, presented an attractive means for the provision of a relatively cheap and very stable telegraph network, with the added advantage of the unification of the telephone and telegraph line plant.

The whole of the main-line telegraph communications has now been converted to voice-frequency operation, line plant to the value of some £2 000 000 having thereby been released to meet the heavy demands for telephone trunks. The economies of voice-frequency working have also enabled a more liberal provision of teleprinter circuits to be made, so permitting a further saving in operating costs by avoidance of the re-transmission of telegrams at intermediate offices. The magnitude of this development will be appreciated from the fact that since 1935 the number of teleprinter circuits has been increased from 650 to 970. In addition, the conversion has had important effects on the operating side, which now enjoys a stability and flexibility of service far superior to anything previously experienced.

It is common knowledge that for many years the telegraph service was faced with a steady decline in traffic, the total number of inland telegrams falling from 55·7 millions in 1922 to 35·3 millions in 1934. The difficulty of preventing a rise in the cost per telegram under such conditions will be readily appreciated, but the forward policy which has been pursued has secured a regular decrease in the cost. Such was the position in 1934 that the prospect of reducing rates could be faced without fear of a prohibitive decrease in revenue. The sixpenny telegram was introduced in July, 1935, and there was an immediate increase in traffic of 34 % over the corresponding period for the preceding year. A most encouraging feature is that the improvement in traffic resulting from the reduction in rates was not only maintained but was, in fact, exceeded in the following year, the figures for the financial year ending 31st March, 1937, being some 40 % greater than those for the year preceding the change in tariffs.

Whether the effects of the reduced tariffs will be to introduce some new factor to arrest the past decline in telegraph traffic, or whether, as has been suggested in certain quarters, the traffic will after a time merely decline on a new curve, remains to be seen. Some optimism seems to be justified from the fact that there was a further increase in traffic during the second year that the new charges were in force, and that for the first 3 months of the current financial year a still further improvement of about 4 % has been obtained. On the other hand, it seems almost inevitable that the growth of the telephone habit will be accompanied by the diversion of traffic from one service to the other. Be this as it may, the policy of securing reductions in operating costs is still being actively pursued and, from proposals now under investigation, it seems probable that still further substantial economies may be realized.

With the standardization of teleprinter working and the building-up of the voice-frequency network, the way has been paved for what now appears to be the next logical step in development, namely that of the establishment of a switched telegraph system utilizing the methods of automatic telephony. The ultimate result of the proposals now under consideration would be the setting-up of a system whereby practically any teleprinter office in the inland service could, by dialling, obtain instant communication with any other teleprinter office. This would enable telegrams to be signalled direct to the office of destination, where this is a teleprinter office, without the necessity for re-transmission at any intermediate offices. As, under the present system, telegrams have, on the average, to be signalled about twice before reaching the final office, it will be seen that appreciable operating economies can be looked for with automatic switching.

To provide a satisfactory grade of service, increased circuit provision is necessary, and it is also essential that the stability of the channels should be such as to enable satisfactory working with the indiscriminate linking together which would occur with switching. The voice-frequency system allows the economic provision of channels of the requisite high grade of transmission.

The proposed circuit provision on main routes is designed to give a grade of service of one engaged call in 500 at times of peak season load, and during by far the greater proportion of the time the grade of service would therefore be considerably better than this. In the final scheme the country would be covered by approximately 30 switching centres, and these would be so interconnected that alternative routes would be available for all calls. The second route would be secured by dialling an alternative number, which will appear in the directory. The proposed layout will also enable all calls to be completed over not more than two voice-frequency channels with two physical extensions, or three voice-frequency channels with short physical extensions, in tandem. The channels will be two-way but will normally only be worked simplex. Duplex working could, however, be resorted to at times of pressure.

Point-to-point circuits will be provided between offices when the direct traffic justifies it, and at any time additional point-to-point duplex circuits can be set up over the switching network if exceptional conditions arise. The reserve of traffic capacity available by this means, the generous basis of provision of lines and apparatus, and the general flexibility and stability of the main network, would appear to be such that in no essential respect should the service under emergency or overload conditions be inferior to that given under similar conditions on the present system.

There will be a considerable decrease in the number of teleprinters required at large offices, owing to the disappearance of the bulk of the re-transmission work, but an increase in the number of teleprinter circuits to out-offices will be necessary to provide an adequate grade of service. Answer-back working as now used on the ancillary system will be adopted to save both operating and circuit-holding times.

The design of the automatic switching circuits has now reached an advanced stage, full use being made of the latest developments in automatic telephony. The most important differences in circuit design arise from the fact that in automatic telegraphy only one type of transmission is available for both the normal signalling facilities necessary for automatic working and the communications on the established calls. On this account, time is the only basis for discriminating between the various types of signals. The problems arising from this and other causes have, however, all been shown to be capable of satisfactory solution. Experimental equipment comprising 22 teleprinter positions and 6 skeleton switching centres has been set up and subjected to engineering and traffic tests, with promising results, and from an engineering point of view there seems to be no doubt that a satisfactory system can be provided. Examination of all the relevant factors, including certain traffic questions and those of costs and savings, have not yet been completed, but up to the present the indications point to the probability that a switched telegraph system would fulfil the traffic requirements of the service and that worth-while savings would result from its adoption.

It is too soon to say what would be the effect on traffic of such a system, but switching holds possibilities other than the reduction of costs, and the improved transit time which would no doubt be secured might, in itself, have a beneficial effect on the volume of traffic.

CONCLUSION

I have essayed to give a brief account of current developments in relation to either cost or quality of service, both of which are calculated to increase future demand. It is this question of demand which is the dominating factor in our policies at the moment. On account of the length to which this Address would have had to be extended, I have refrained from describing the many technical developments which are taking place in submarine cables, radio communication services, wire broadcasting, and television.

The rapid developments in the telecommunication field are the product of the many-sided activities of research, and the function of the engineer is to relate these activities to the creation of a public demand and to satisfy it at reasonable cost.

WIRELESS SECTION: CHAIRMAN'S ADDRESS

By T. WADSWORTH, M.Sc., Member.

"A REVIEW OF IMPROVEMENTS IN CINEMA SOUND REPRODUCTION SINCE 1928"

(*Address delivered 3rd November*, 1937.)

INTRODUCTION

I wish to express my appreciation of the honour that you have conferred upon me in electing me Chairman of this Section. As the Chairman's Address is not open for discussion, I shall endeavour to avoid controversial subjects and shall confine my remarks to a review of the advances in cinema sound reproduction which have been achieved since 1928.

Improvement in the quality of sound reproduction in the cinemas of this country since the introduction of talking pictures in 1928 has been rapid and is still proceeding. The introduction of any new recording technique is followed immediately by the announcement of an improved sound-reproducing system capable of demonstrating the latest product of the recording studio. The continued study of the acoustic properties of cinemas, both in the design of the building and in the treatment of troublesome walls and other surfaces with acoustic material, has resulted in a steady and almost imperceptible improvement in each succeeding cinema, which over a series of years has been as marked as the changes in the equipment itself. Attention to details in the installation, and in particular to the correct location and design of the loud-speaker units, has contributed to a final result which bears little resemblance to early examples of sound-film reproduction.

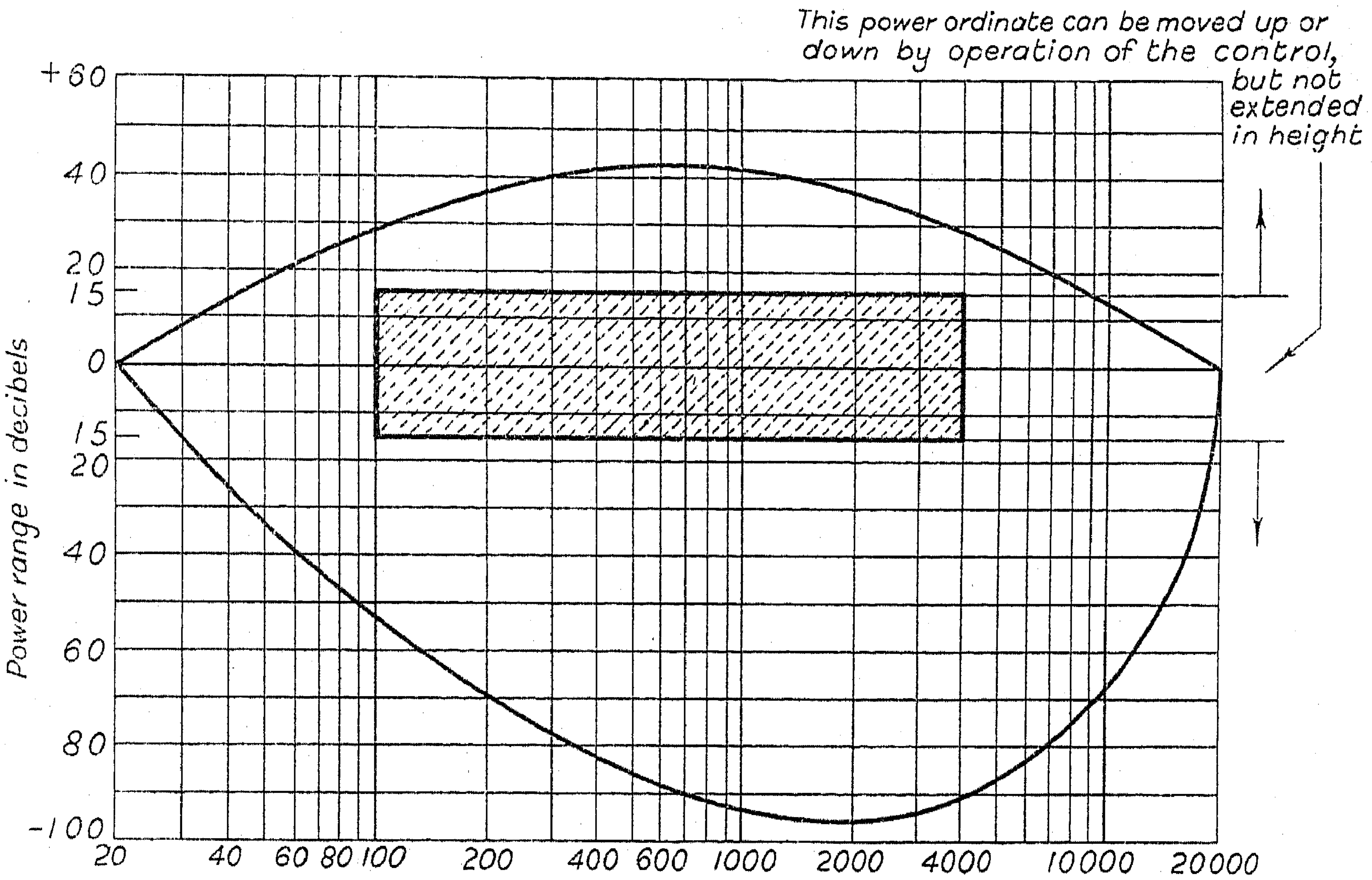


Fig. 1.—Average reproducer overall characteristic (1928–30).

It is the purpose of this Address to trace in the broadest manner the course of these developments and to indicate the trend of further research.

GENERAL CONSIDERATION OF EARLY EQUIPMENTS—1928–30

The average human ear can appreciate sounds having frequencies ranging from 16 to 20 000 cycles per sec., but its discrimination of power differences varies widely over this range. At a frequency of 1 000 cycles per sec. a power range of 130 decibels can be appreciated between the threshold of audibility and maximum audibility.

The early equipments of 1928–30 had a frequency range of 100 to 4 000 cycles per sec. and a power range of 30 db.; the reproduction was also marred by frequency and amplitude distortion introduced by the equipment and by the acoustic properties of the halls in which the equipment was installed. This power range can of course be situated at any region of the ear sensitivity curve between threshold and maximum limits of audibility, and its position depends upon the average maximum intensity used in a particular cinema (Fig. 1). The difficulty of maintaining a recording power range of 30 db. on the film led to serious deformation of the character of the recorded sound. Distortion introduced by the film-propelling mechanism took the form of gearwheel and sprocket tooth ripple, which modulated the sound record and produced harsh and "throaty" reproduction.

The need for acoustic treatment of the halls was recognized from the first, but little was known of the absorption properties of the material available or of the measurement of reverberation and its optimum value for a given auditorium. It became the practice to treat the walls with sufficient material to bring the reverberation time of a 500-cycle note to somewhere between 1¼ and 1½ sec., depending upon the size of the hall. The reverberation periods of notes of higher or lower frequency were ignored, and the usual result was that reverberation was too high at low frequencies and too low at high frequencies. This gave accentuated bass response and a hard "dead" response of the higher frequencies.

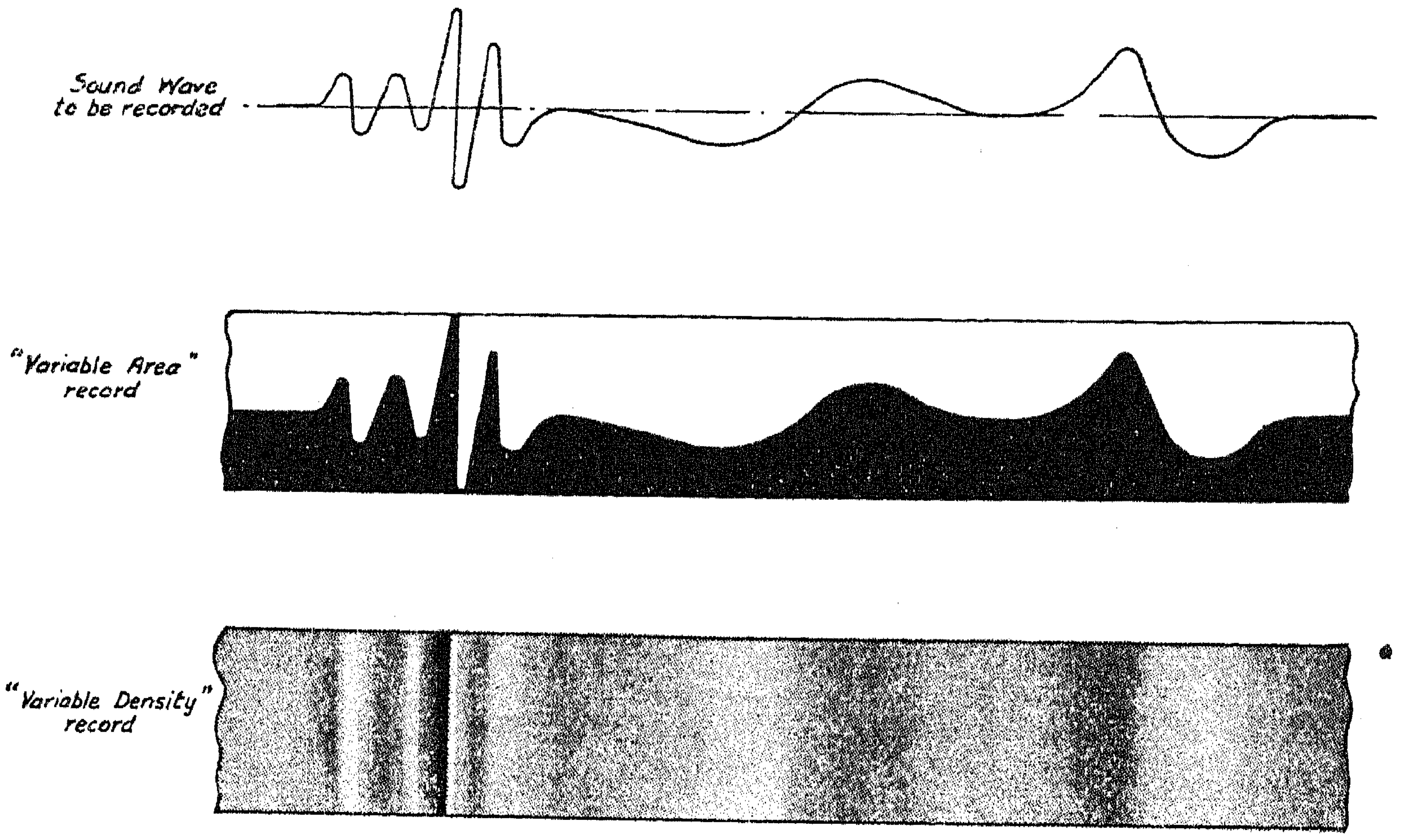


Fig. 2.—Diagrams to illustrate that a sound record can be portrayed as a variation of either shape or density of photographic material.

OUTLINE OF DEVELOPMENTS SINCE 1928–30

In tracing the developments that have taken place since these first sets were installed, the survey is divided into four sections:—

- (*a*) The sound record on the film.
- (*b*) The sound head (or film-propelling mechanism and scanning system).
- (*c*) Amplifiers and loud-speakers.
- (*d*) Cinema acoustics.

(a) The Sound Record on the Film

The film forms the first link in the reproducing system. A photographic image can portray both shape and density, and so two distinct forms of record are available, known as "variable area" and "variable density" recording respectively (Fig. 2). An ideal in either case is that the sound-modulated light beam imaged on the film shall be infinitely narrow in a direction perpendicular to the film travel. In practice the speed of the film is fixed at 18 in. per sec. and the upper-frequency limit of recording is fixed by the minimum possible width of the recording slit and the photographic properties of the film. In addition, the stray light of the recording optical system must be zero.

The photographic limitation to the frequency range is due to lack of resolving power of the emulsion. This can roughly be defined as the emulsion's ability to record fine detail. Light falling on the silver-halide particles of the emulsion during the recording or printing operation is scattered and exposes other neighbouring particles. Thus instead of a sharp, well-defined change of contour from black to white the boundary of the sound wave has a density gradient (Fig. 3). This light scatter is not serious at low frequencies where the wavelength is large, but becomes serious at high frequencies and produces a loss of output and the introduction of spurious harmonics in the case of variable-area recording (Fig. 4).

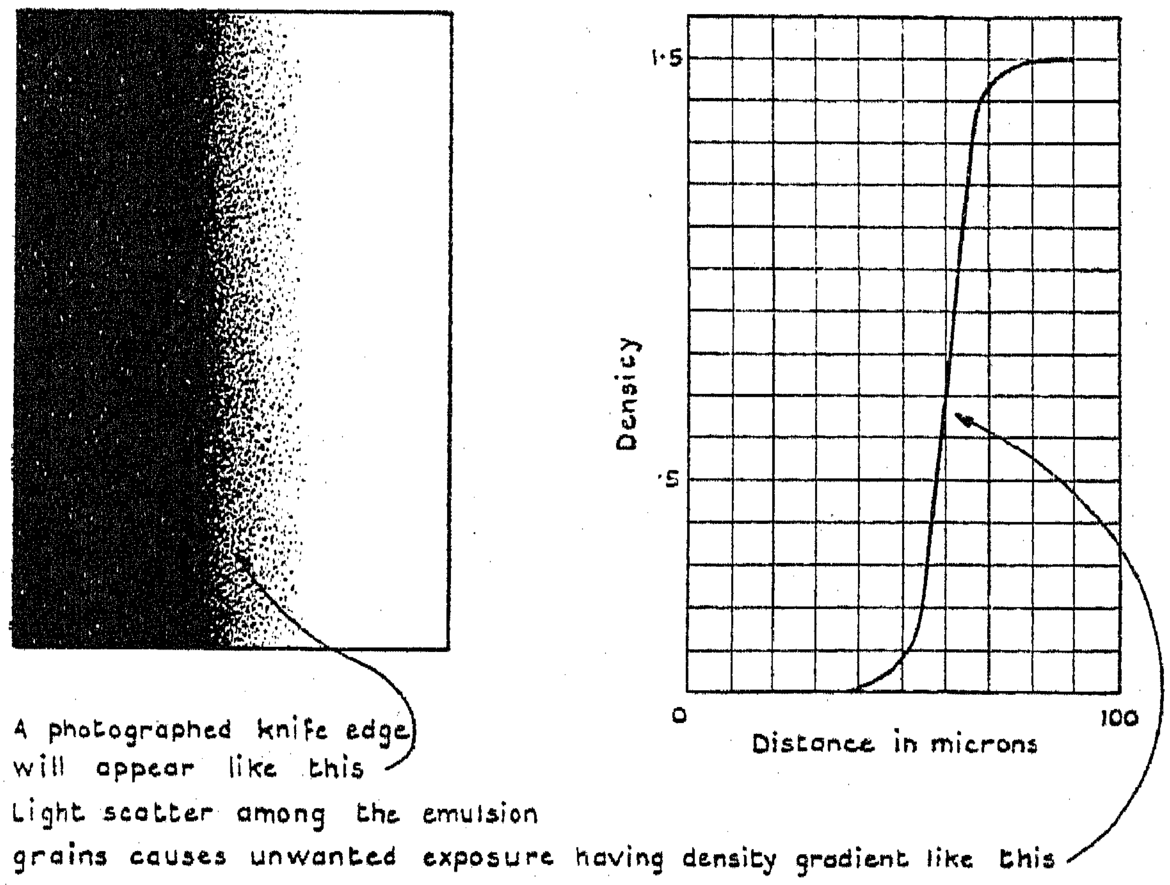


Fig. 3.—Diagrams illustrating limitation of record definition by emulsion resolving-power.

In addition to the limitation of finite slit-width and the photographic light scatter, early recordings were limited still further by the mechanical details of the recording light modulator, and at the lower end of the frequency scale by the coupling circuits in the recorder amplifier. The final result was a frequency range on the film of 100–150 to 4 000–5 000 cycles per sec.

The volume range of the film is expressed as the ratio of the amplitude of the maximum signal that can be recorded on the track to the amplitude of the background noise from the film itself. To be inaudible, the background level should be 30 db. below the maximum signal, but this cannot be achieved at present. The maximum amplitude of the track is 0·071 in., and the equivalent amplitude of the background noise of an elementary variable-area track is approximately 0·0025 in., giving a signal/background ratio of 25 to 30 db.

One of the earliest improvements introduced into sound recording was the principle of ground-noise elimination. The background noise from a film is due to accidental variations in film transmission over extremely small areas and to shot effect in the photocell. If the track transmission is made proportional to the recorded amplitude the background noise is reduced to the lowest possible value, and the volume range increased accordingly (Fig. 5). To achieve this end the clear part of the sound track is reduced to a minimum. Ground-noise elimination has been achieved in various ways for the different types of track, and has resulted in an increase in volume range of 10 to 15 db.

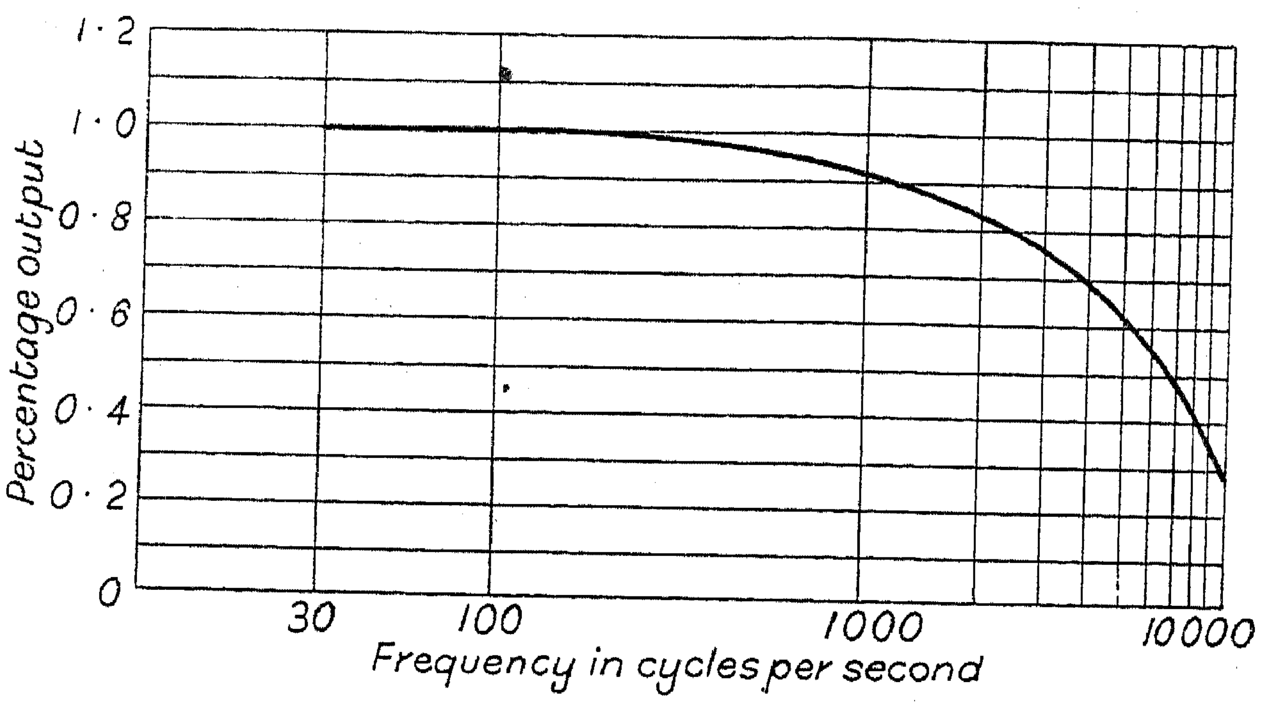


Fig. 4.—Graph showing attenuation with frequency caused by "scatter exposure." The curve indicates the theoretical minimum attenuation due to photographic defects in a 35-mm. negative record.

Continued efforts were made to extend the frequency range to 10 000 cycles per sec. Improved recording light modulators were built with their mechanical resonance beyond 10 000 cycles per sec., and film recorders were improved to overcome sprocket ripple. Constant-frequency recording showed good sound records up to 10 000 cycles per sec., which could be demonstrated over improved reproducers, but the result in the cinema was discouraging. The reproduction of sibilants was harsh, and what was known as "S distortion" became common. As a result the frequency range of the reproducers was still curtailed to about 6 000 cycles per sec. The cause of the trouble was traced to the lack of emulsion resolving-power previously mentioned. Fogging in the valleys of the high-frequency records produced not only attenuation of the output but also rectification.

The extension of the recording range at the lower end made audible at 30 cycles per sec. the change in mean track transmission used for ground-noise elimination. These difficulties were met by control of the processing and the redesign of the ground-noise elimination system, but the results still left much to be desired and development centred round methods of recording that would avoid the difficulties. Some improvements can be claimed for such forms of variable-area tracks as the single and multi-bilateral, because here the amplitude of an individual component track is lowered at a given frequency and so the effective valley angle is increased. In other words, all effects due to lack of emulsion resolving-power are somewhat lessened.

The greatest advance of recording technique which has occurred recently, and which is, I believe, still not in use commercially, is termed push-pull recording. In principle the positive and negative half-cycles are divorced, and recorded on either side of a clear space along the track centre. In addition, both positive and negative half-cycles are halved in amplitude and each half amplitude recorded symmetrically on either side of axes displaced one-quarter and three-quarters of the track width respectively.

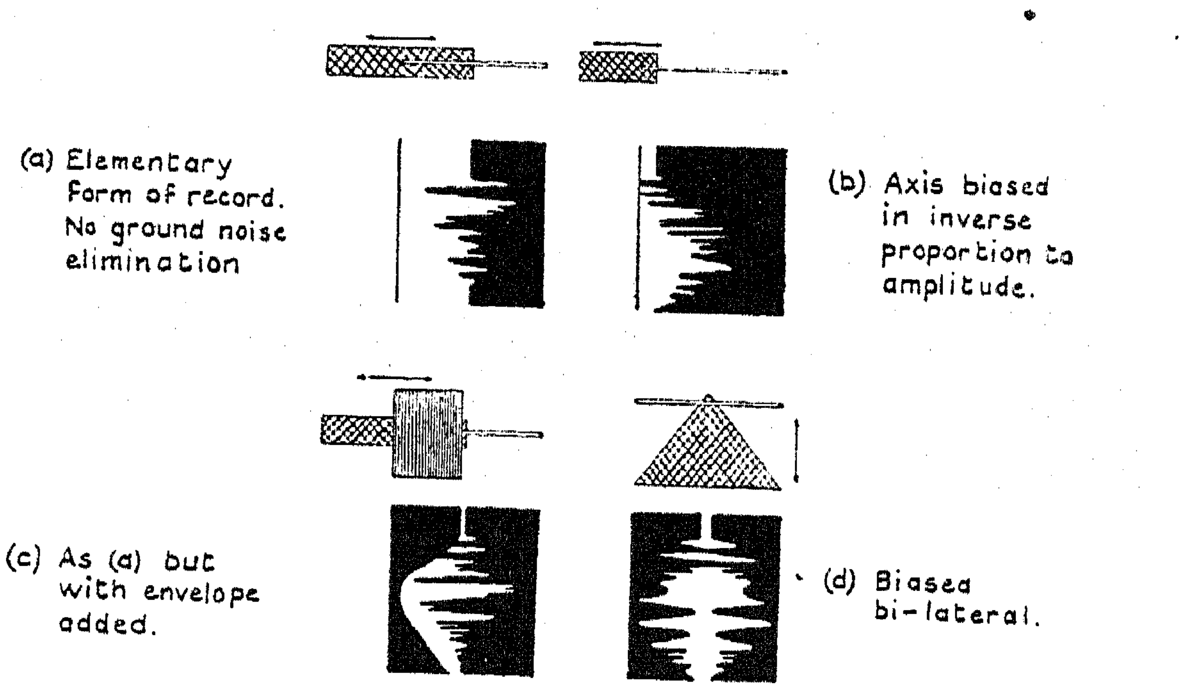

(a) Elementary form of record. No ground noise elimination
(b) Axis biased in inverse proportion to amplitude.
(c) As (a) but with envelope added.
(d) Biased bi-lateral.

Fig. 5.—Ground-noise elimination on variable-area positive record.

For ground-noise elimination, all unnecessary clear track is removed. The rate of change of axis or envelope must be less than that of the minimum reproducible frequency.

Many optical arrangements may be used for reproduction, but in principle the light modulated by the two halves of the track must be directed to two separate photo-electric cells or to two separate cathodes in one cell. The cathodes are connected each to one half-winding of the push-pull transformer.

This kind of track has two important advantages. In the first place, ground-noise elimination is provided automatically because on the positive film the mean transmission is always proportional to the amplitude. The second advantage is concerned with the reduction of harmonic distortion due to lack of resolving power and due to stray light following the recording edge. In the case of any other system of variable-area recording the density gradient at the record edge extends on the same side of the axis for both positive and negative half-cycles. As previously mentioned, this gives rise to a shifting of the axis, which introduces a harmonic content variable with frequency and an attendant superimposed distortion if the track amplitude varies at audio frequency. In the case of push-pull track the image-spread occurs in opposite directions, and there is no axis-shift. This does not of course remove harmonic distortion completely, but only one cause of it.

(b) The Sound Head

Under this heading can be included all equipment which has as a primary function the task of converting the photographic record into equivalent electrical energy.

Equipment for propelling the film at constant speed in the correct path.

The major difficulty in the way of obtaining sufficiently constant velocity of film travel is the fact that film shrinks irregularly throughout its useful life. In the picture projector the speed of propulsion must be related to the perforation pitch to obtain registration. It is necessary to propel the film by means of its perforations in the sound head, also because the actual length of film per unit perforation pitch is a variable quantity. The tooth pitch of the propelling sprockets is fixed, whereas the perforation pitch of the film is continually varying and therefore constant velocity of propulsion at the sprocket is impossible.

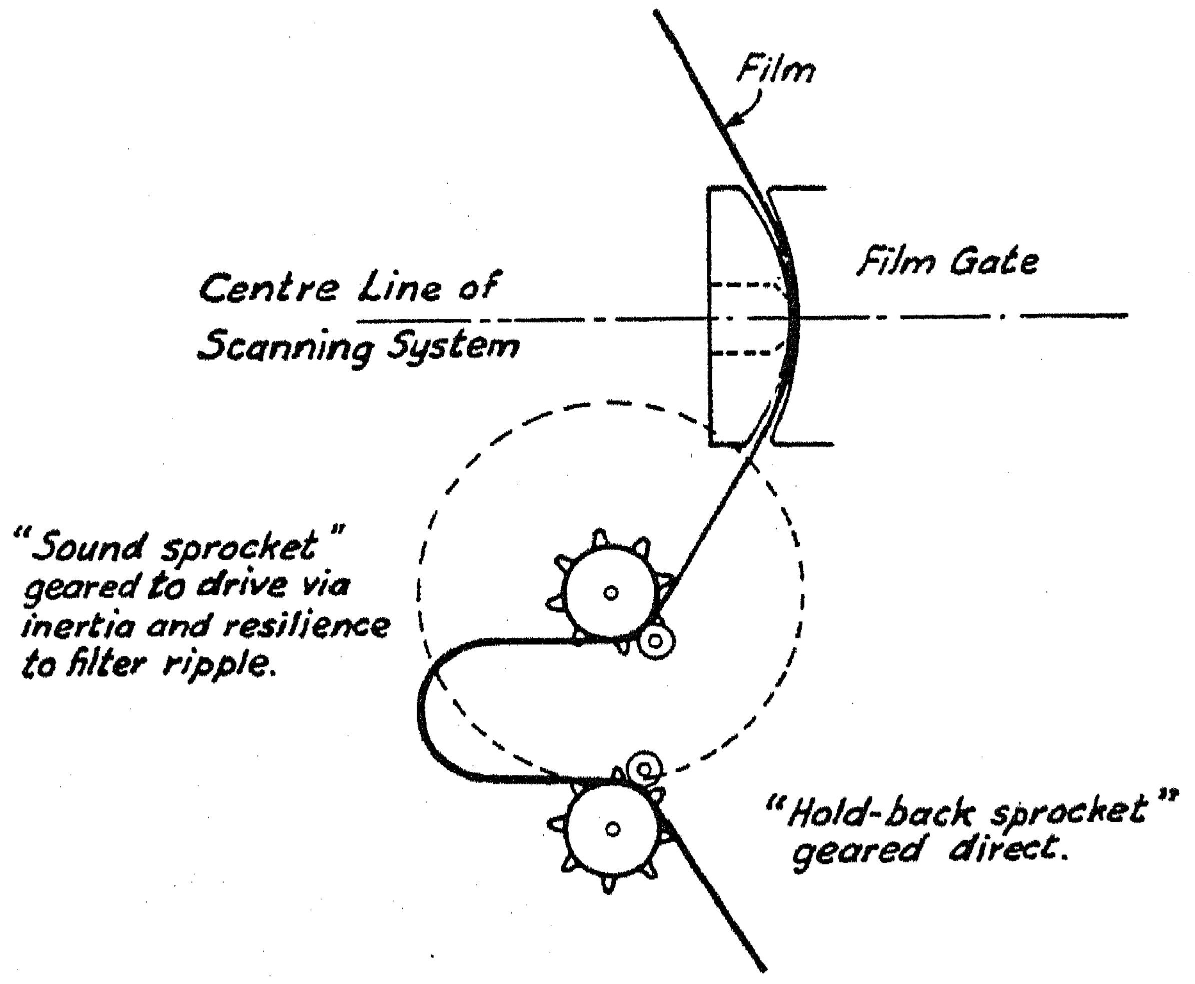

Film
Film Gate
Centre Line of Scanning System
"Sound sprocket" geared to drive via inertia and resilience to filter ripple.
"Hold-back sprocket" geared direct.

Fig. 6.—Diagrammatic arrangement of simple sound head.

In addition to sprocket-tooth ripple, irregular film propulsion is caused by sprocket and shaft eccentricity and by disturbances due to gears and driving chains. All these causes of irregular propulsion result in frequency modulation of the reproduced sound. The maximum acceptable value of frequency modulation is related to the power range of the reproducer equipment because the aural effect must be kept below the minimum signal. Increases of power range have all been achieved by lowering the total background noise so that a smaller minimum signal can be reproduced. (This statement excludes volume expansion, which will be referred to later.) The extension of the power range in the direction of the minimum signal has called for a corresponding decrease in the value of frequency modulation due to sprocket ripple, etc.

In the early days of the talking film the available power range of 35 db. called for certain limits of eccentricity and partial filtering of gear and chain disturbances. This was usually achieved by a mechanical filter system in the drive to the sound sprocket, and the isolation of "take up" disturbance by following the sound sprocket by a free film loop prior to a "hold back" sprocket: this mechanical filter usually consisted of inertia attached to the sprocket shaft receiving rotational power through a resilient member (Fig. 6), the whole being damped to a value of approximately half critical damping by means of fluid friction.

The more recent increase of power range to 50 or 55 db. has called for more complete filtering in the existing position and the addition of a mechanical filter to limit the amplitude of sprocket-tooth ripple and sprocket eccentricity. This must obviously be located between the "sound sprocket" and the scanning point, and a convenient mechanical arrangement consists in what is usually referred to as a "drum head" (Fig. 7). The track is scanned as the film moves in contact with the periphery of a rotating drum. This drum has associated with it an inertia member which operates in conjunction with film loop resilience between the drum and the towing sprocket. Free oscillation of such a combination has been damped in various ways, notably by eddy-current coupling with an additional inertia member, or by separating the original inertia member into two components of widely differing inertia with fluid frictional coupling. The major portion of the inertia is free running, and the minor portion solidly coupled to the film drum.

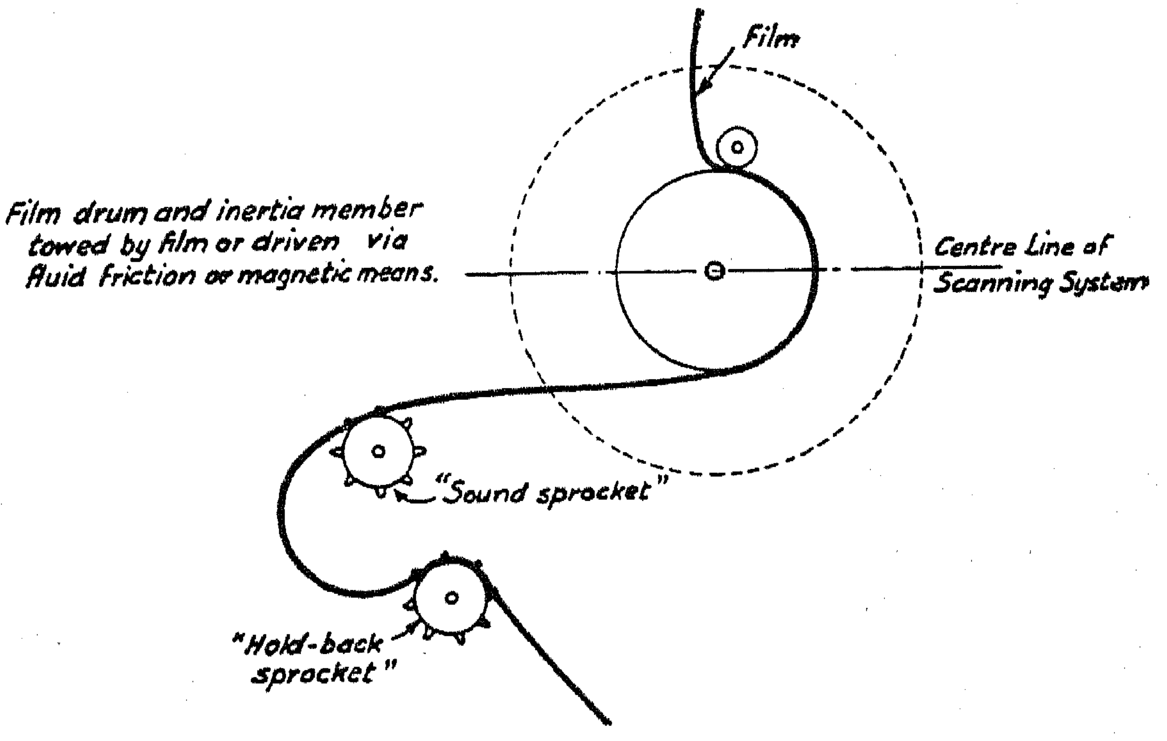

Film
Film drum and inertia member towed by film or driven via fluid friction or magnetic means.
Centre Line of Scanning System
"Sound sprocket"
"Hold-back sprocket"

Fig. 7.—Diagrammatic arrangement of "drum" sound head.

The "sound" sprocket which provides the driving force for this assembly may still be driven via its own mechanical filter system to lower the value of transmitted gear and chain ripple. Alternatively, the drum filter system may be sufficiently large to take care of all mechanical frequency modulation. This latter is difficult to achieve if the film is called upon to transmit all driving power to the drum system. The eddy-current filter system, however, provides an ideal means for supplying rotational power to the drum, leaving the film to supply only sufficient power to hold the drum at the mean film velocity.

The drum head in its various forms has another advantage over a fixed scanning gate in that it prevents the "pile up" of emulsion with "green" film. This occurrence normally changes the plane of the track at the scanning point, with consequent loss of optical focus and attenuation of the frequency characteristic.

The optical scanning system and photocell.

It is probable that more development work remains to be done on this part of the equipment than on that discussed in the previous section.

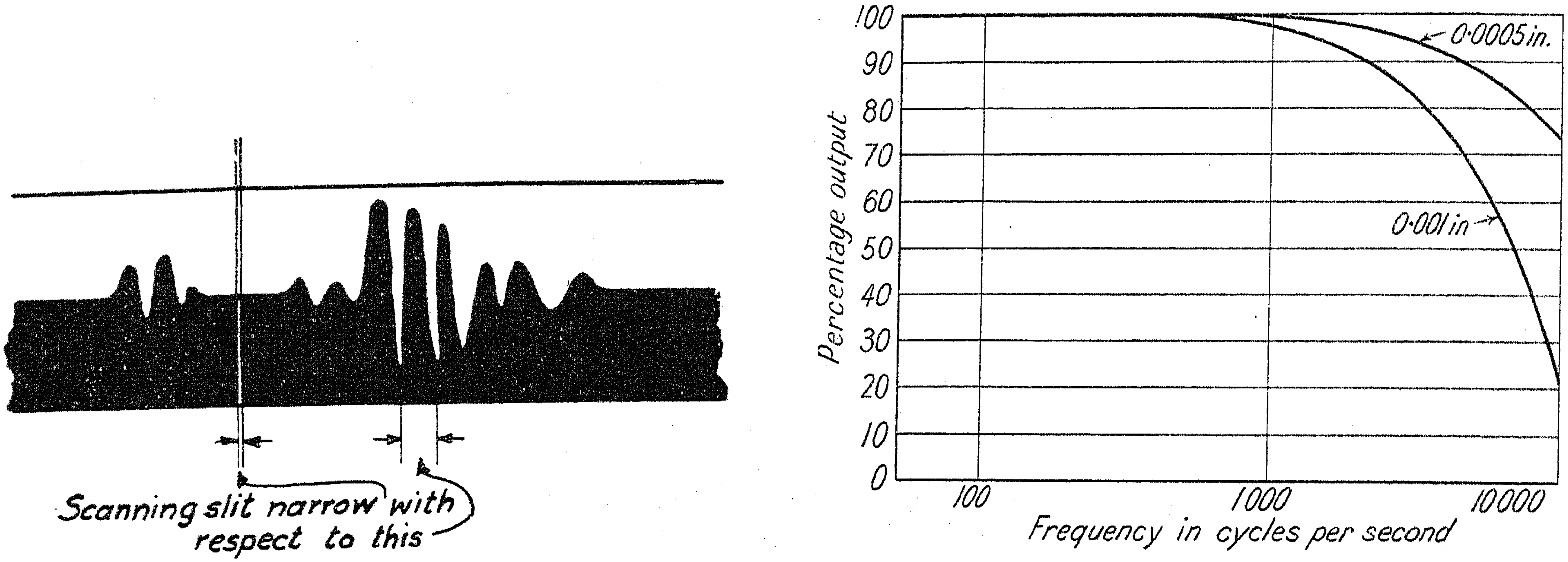
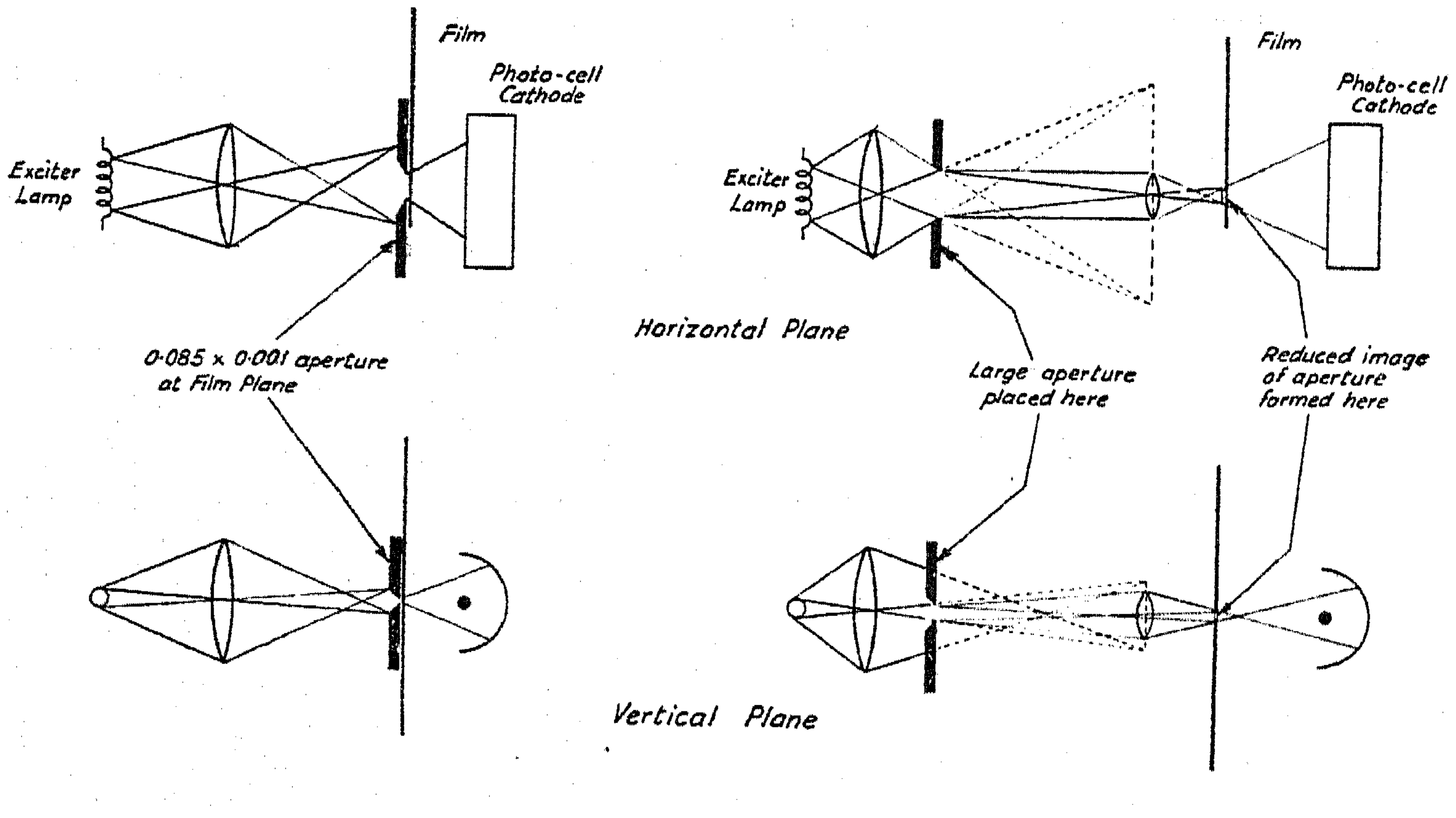


Fig. 8.—Diagrams illustrating that the recorder and reproducer scanning slits must be narrow by comparison with the recorded wavelength of highest frequency.

NOTE.—The right-hand diagram shows the attenuation with frequency for 0·0005-in. and 0·001-in. slits.

The sound track is scanned by a slit of rectangular area bounded by the full sound-track width but very narrow in a direction longitudinal to the film travel. The actual dimension in this narrow direction is determined by the velocity of film travel and the permissible attenuation over the frequency range to be reproduced (Fig. 8). It is apparent that the scanning slit must be narrow compared with the wavelength of the highest frequency recorded on the track, because when the slit width becomes equal to the recorded width of the cycle the modulated output at that frequency will be zero.


Film
Photo-cell Cathode
Exciter Lamp
0·085 × 0·001 aperture at Film Plane
Film
Photo-cell Cathode
Exciter Lamp
Horizontal Plane
Large aperture placed here
Reduced image of aperture formed here
Vertical Plane

Elementary Arrangement. *Normal "Imaged Slit" Arrangement.*

Fig. 9.—Two methods for scanning "track."

For 35-mm. film in commercial practice the track wavelength at 10 000 cycles per sec. is 0·0018 in. The effective width of the film scanned at any instant is usually 0·0004 or 0·0005 in.

The simplest way of providing the required scanning is to place a rectangular aperture of the required size in contact with the emulsion side of the moving film together with a source of illumination on one side and a photo-electric cell on the other. This elementary method was used in the early days, but was soon discarded owing to the mechanical difficulties of making a slit of the required narrow dimension and keeping it free from dust and dirt during operation.

A logical development of the foregoing was to provide a slit of, say, 5 to 10 times the required size and use an image of this slit formed on the film by the use of a corrected objective lens (Fig. 9). Illumination is provided by means of a single-coil horizontal-filament lamp. The filament image is formed in the objective by means of a condenser and the mechanical slit placed at the waist of the beam. This general arrangement has become almost standard practice.

It is possible to reverse the conventional layout and use what is termed the projection scanning system. The sound track is illuminated in the same way as the mechanical slit in the previous case, and an enlarged image of the illuminated track formed on the slit is placed with its objective at the rear of the film. This arrangement has particular optical advantages in a system designed for the production of " push-pull " track.

In passing, it should be mentioned that some work has been done on systems employing a single stretched horizontal wire filament lamp imaged directly with the required reduction on to the track. Optically this is ideal, but it is very difficult to make a filament of the required size which will remain exactly straight and have a constant temperature at all points along its length.

Other improvements which have taken place can be summarized as follows:—

The accuracy of form of the image slit has been improved by paying particular attention to the requirements of optical correction in the objective. The caesium photocell commonly used has a spectral sensitivity composed chiefly of two peaks, one in the red and the other in the violet end of the spectrum. As the energy emission of the exciter lamp is all in the yellow to infra-red end, it has been found advisable to provide chromatic correction of the objective for a band in the red. A second factor which must be considered in this connection is the depth of focus of the objective related to the possible movement of the moving film from the plane of nominal focus.

The distribution of illumination along the length of the slit image is of great importance in the reproduction of variable-area track. A falling-off at the slit ends due to optical characteristics and a variation along the length due to filament structure must be taken care of, and these factors have only recently received the attention which they deserve.

Unequal sensitivity over the cathode surface of the photocell has sometimes been overlooked, and modern apparatus takes special care to ensure that the modulated light falling on the cell cathode covers a constant area and varies only in intensity.

Finally, it can be stated that improvements have been made in the means for focusing and aligning accurately the slit image upon the track, particularly the normality of the slit length to the direction of film motion. With increases of reproduced frequency-range, it has become more and more important to work to very small tolerances in this connection.

(c) Amplifiers and Loud-Speakers

It is almost essential that the improvements which have been made in amplifier design should be considered in relation to the loud-speakers which they are to feed.

In early equipments the amplifier frequency-response was limited to the range between 100 and 5 000 cycles per sec. and had its peak at 4 000 cycles, partially to compensate for attenuation in recording and loud-speaker characteristics. The power range of the amplifier was considerably restricted by residual noise in the valves and thermal agitation in the coupling circuits. Its value was usually little more than that available from the film (approximately 30 db.). As the amplifier range was at least as great as the film range, it was considered to be satisfactory, although modern practice obtains a volume range of 70–75 db. (Fig. 10).

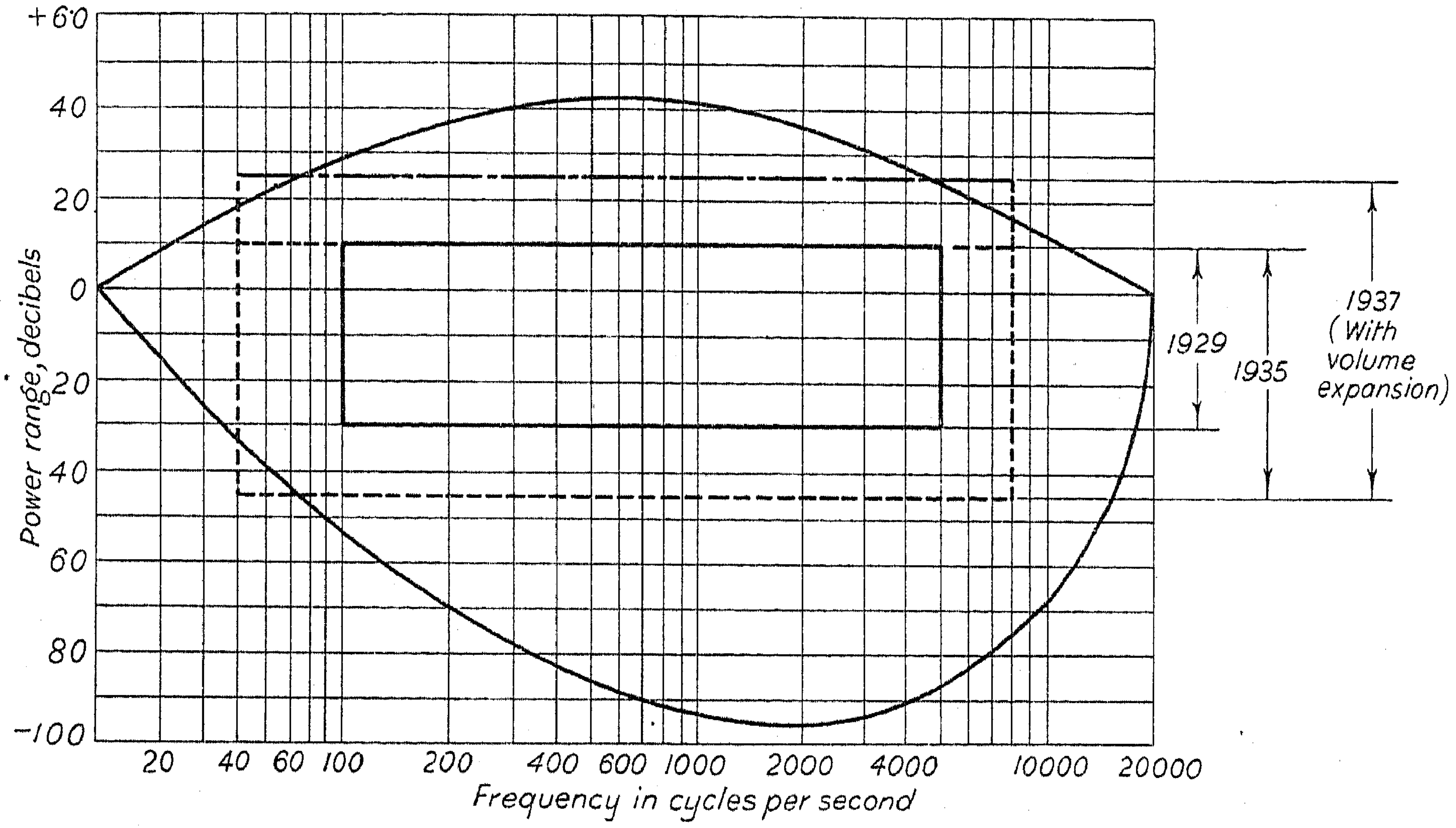


Fig. 10.—Improvements in amplifier power range, 1929–37.

Amplifier distortion was measured as the percentage of 2nd harmonic introduced in the output circuit when a sinusoidal voltage was applied to the last-stage grid. A value of 5 % 2nd harmonic at full load was considered to be satisfactory and all higher harmonics were neglected, as they were assumed to be of lower amplitude and less audible.

The trend of amplifier design has been towards a wider frequency range, a reduction in background noise with its corresponding increase in available power range, and a reduction in harmonic content. A frequency range flat between 50 and 8 000 cycles per sec. is found to be satisfactory at the present stage of the art, although there is no difficulty of course in considerably extending this range in either direction (Fig. 11). It is found, however, that an upward extension increases the background out of all proportion to the gain in quality, whilst a downward extension would interfere too much with the problem of providing the ground-noise elimination on the track. These two points have been considered in the first section of this Address.

It is now agreed that harmonics higher than the 2nd, whilst of smaller amplitude, are liable to be more readily audible as distortion; 1 % of 7th, 9th, 11th, or 13th harmonic can be detected as readily as 5 % of 2nd harmonic. In modern amplifiers, therefore, the overall harmonic distortion is limited to a value of less than 1 % of the fundamental over the whole power and frequency range.

Power outputs used vary largely with the size of cinema and the type of loud-speaker employed. Outputs of from 5 to 75 watts are common. In early equipments there was a tendency to use very large power outputs in an attempt to compensate for lack of intelligibility and low loud-speaker efficiency due to limited frequency range. Following this there was a general tendency towards lower powers, but to-day outputs are again on the up grade to allow for the incorporation of volume expansion.

One of the most interesting of recent developments is the extension of the power range by a volume-expansion circuit. The circuit is so arranged that small input signals are amplified less than large input signals (Fig. 12). The result is an automatic extension of the volume range of some 10 to 15 db. To make the maximum use of automatic volume expansion, it is necessary to use automatic volume constriction during the recording process to some predetermined characteristic, and then to introduce the equivalent expansion in the reproducer. Restriction of the volume range is always necessary during recording and is achieved at present by manual control, but, even with the incorrect matching of the manual control and automatic expansion, considerable improvement is achieved in the sound reproduction by the volume-expander circuit. The improvement is less marked on speech than on music, but some advantage is gained here by the reduction of background noise during all low-amplitude sections.

Early loud-speaker assemblies consisted of groups of cone-type moving-coil speakers mounted on flat baffles, arranged down each side of the screen, or two or four horn-type speakers driven by moving-coil units and assembled behind the screen and in the orchestra pit. The frequency response was limited to the range 150–4 000 cycles per sec. approximately, generally with a considerable peak in the response in the 2 500- to 4 000-cycle band. Non-linear distortions were appreciable.

Directional baffles and exponential horns fitted to moving-coil speaker units increased the efficiency and the directional control of the sound in consequence; commercial speakers were generally of two types—the large-cone short-horn and the small-diaphragm long-horn types. A similar order of performance was produced from either type.

The limited frequency-range offered opportunities of improvements, and the first approach to the problem consisted of adding extra speakers to cover the bands above 4 000 cycles and below 150 cycles per sec., or in some cases modifying the existing speaker to improve the low-frequency response and adding extra speakers to cover the range above 4 000 cycles per sec. In the 3-way speaker system the extension of the low-frequency end of the range was obtained by a group of two, three, or four large-diameter cones mounted on a large flat baffle; while in all cases the extension of the high-frequency end was obtained by small high-frequency speakers, generally mounted in the mouth of medium-frequency speakers.

Filter networks were added in the amplifier output circuit in order to divide the frequency range between speakers.

The extension of the upper end of the frequency range to 10 000 cycles per sec. proved a little premature, mainly owing to the emphasis it placed upon distortion occurring in certain parts of the system, but in part owing to the method of extending the range.

Further research made it possible to cover the whole range of 50–8 000 cycles per sec. with a maximum of

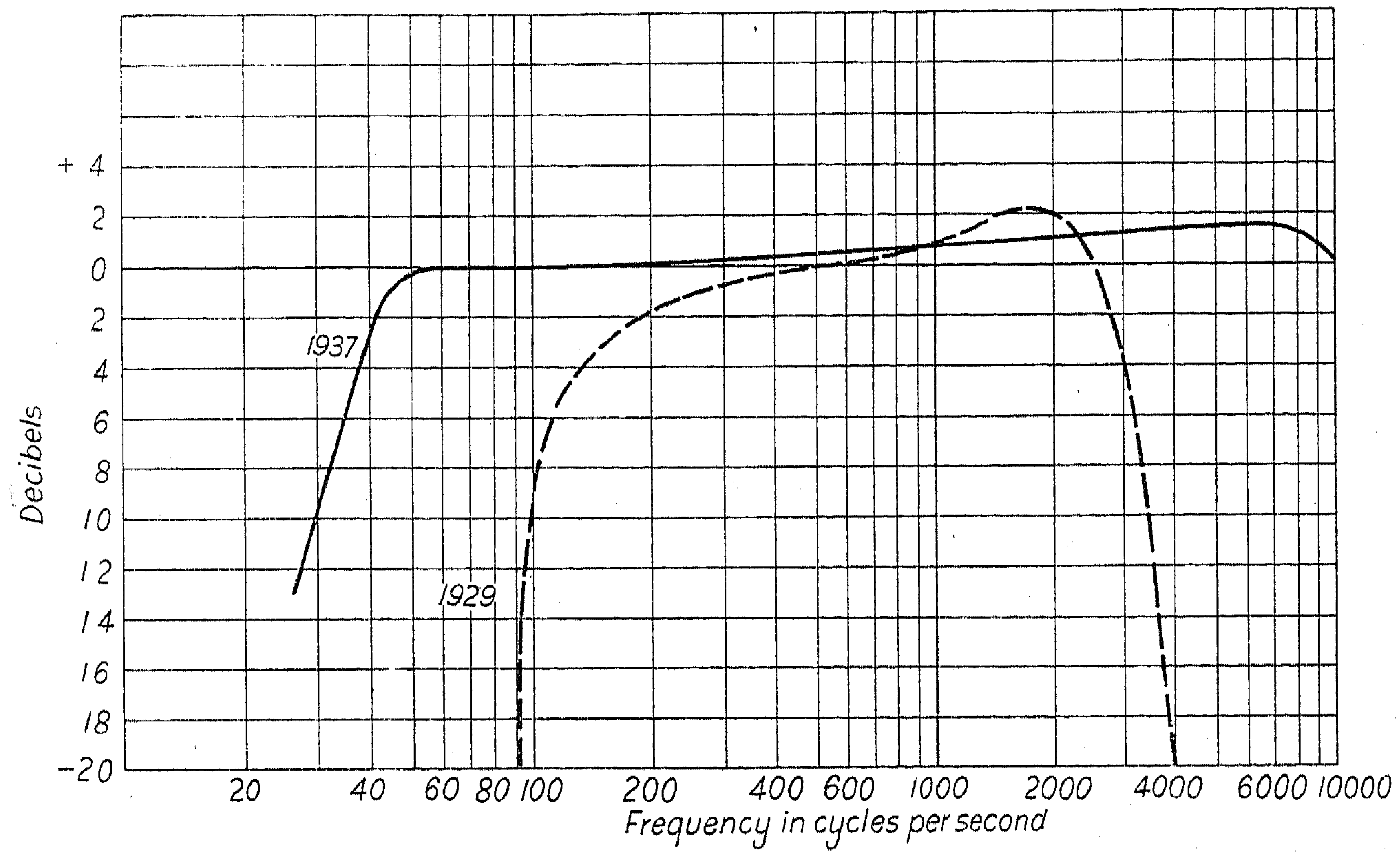


Fig. 11.—Improvement in amplifier frequency characteristic, 1929–37.

two speaker groups, one group generally consisting of several large cones in a folded horn covering the range from 50 cycles to 300–500 cycles; and the second group consisting of one, or, more rarely, two horns, driven by two units covering the range from 300–500 cycles to 8 000–8 500 cycles.

Careful design of the low-frequency and high-frequency speaker units produced a characteristic which deviated from the mean by a much smaller amount, and reduced the non-linear distortion prevalent in earlier systems (Fig. 13).

Non-uniformity of distribution at high frequency was overcome by subdivision of the high-frequency horn into a large number (3–18) of smaller horns, all mounted together and driven from a single header operated by two units wired in parallel to minimize risk of failure.

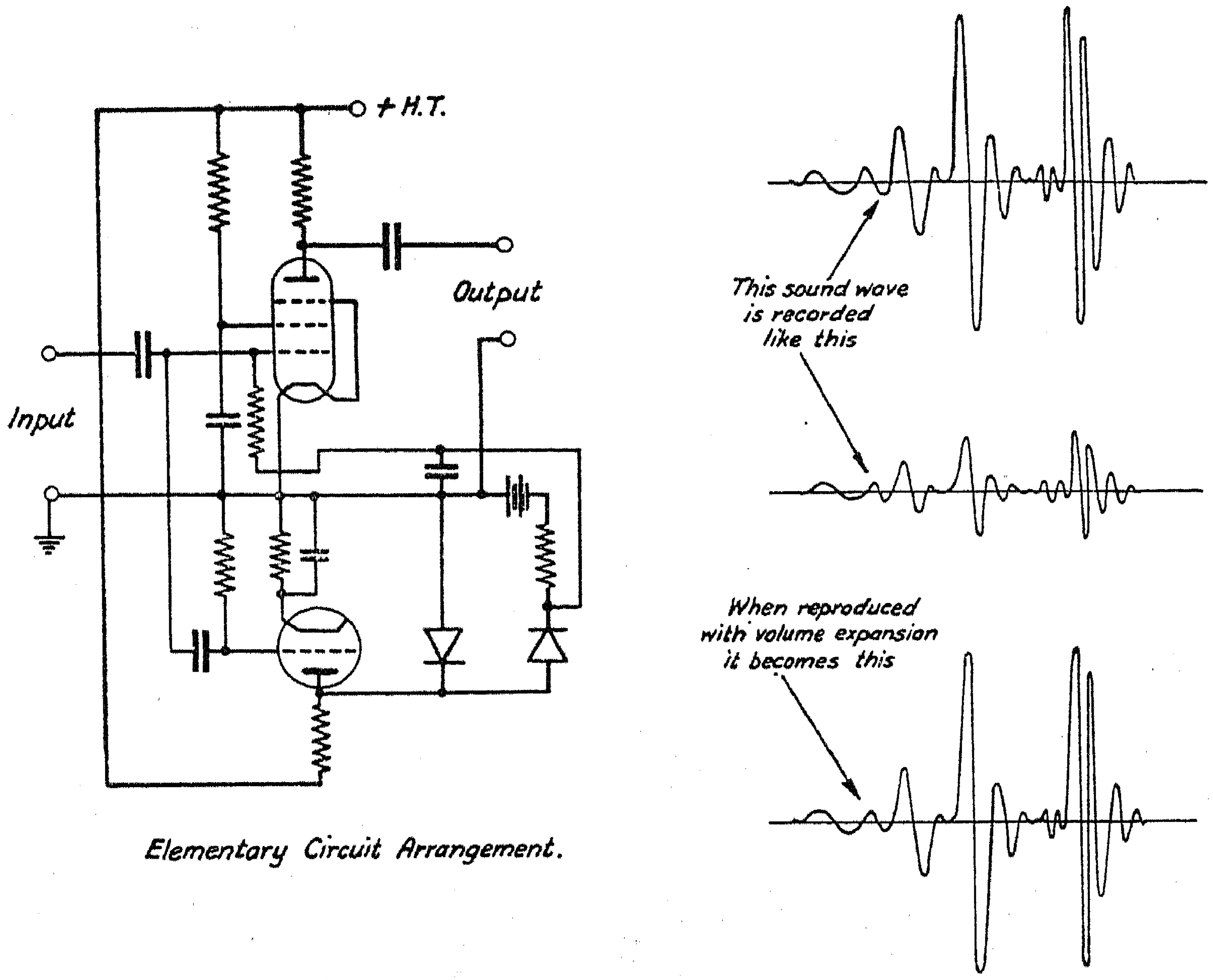

+ H.T.
Output
Input
Elementary Circuit Arrangement.
This sound wave is recorded like this
When reproduced with volume expansion it becomes this

Fig. 12.—Volume expansion in reproducer: effective increase in power range 10–15 db.

Transient distortion is minimized by the improvement in frequency range, by achieving linearity within the range, by the improved damping of the moving system due to parallel operation of speaker units, and by the use of amplifiers presenting a low output impedance to the speakers together with gap diversities in the region of 20 kilolines per cm^2. This is the present state of the art. Perfection has not been reached.

Future development along the same lines will consist in further improvements in efficiency, linearity of response, and reduction of non-linear distortion. It is a little more difficult to forecast the development along different lines, but it seems probable that single-unit mechanism covering the complete range will eventually return.

(d) Cinema Acoustics

It is impossible to conclude this survey of sound-film equipment without considering cinema acoustics. In fact, it is probably true to say that the next step towards perfect sound rests with the acoustics of the auditorium rather than with the apparatus.

The acoustic properties of the auditorium have always been the greatest variable and the one most difficult to cope with in sound reproduction. The shape, size, properties, and materials used all play a most important part in the final result, and even to-day it is difficult to predict with certainty the effect of any scheme unless it is an exact copy of some previous construction.

W. C. Sabine laid the groundwork for auditorium acoustics and established the relation between optimum reverberation time and volume of the hall for good aural results. If the reverberation time is too long, successive sound impulses are interfered with by the reflected sound waves of previous impulses, and the intelligibility of speech is lost, while too short a reverberation time causes a hard "dead" quality in the reproduction. The accuracy of Sabine's curve was surprising, obtained as it was by experimental methods from a study of numerous halls, and more recent data calculated on the basis of physiological characteristics of the ear show a close agreement with the original data.

The reverberation time is controlled by the quantity and absorbing characteristic of all sound-absorbing material in the auditorium, including the audience, chair upholstery, carpets, curtains, etc., and in all the early work the distribution of the sound absorbent was not considered important as long as the requisite quantity was present. In cinema auditoriums, however, the position of the sound-absorbing material is important, because the source is situated at one end of the hall and sound is directed down the hall on to the audience. First reflections from the walls and ceiling are very important, and in many cases over-treatment of the hall has resulted from the addition of too much sound-absorbing material on these danger points.

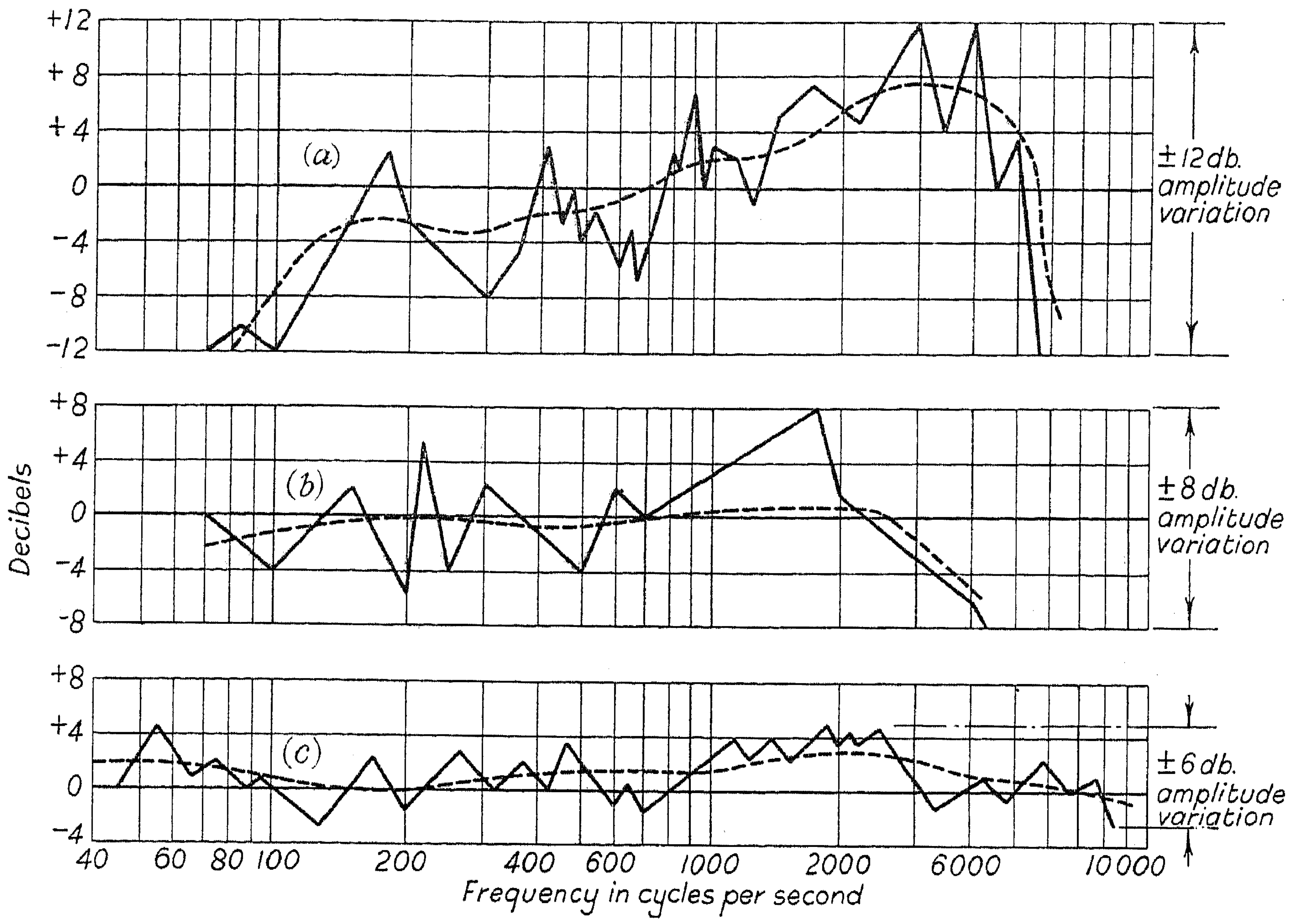


Fig. 13.—Frequency characteristics of loud-speaker assemblies, 1929–37.

(*a*) Loud-speaker on flat baffle, ± 5 db. spread from mean.
(*b*) Loud-speaker in directional baffle, ± 6 db. spread from mean.
(*c*) 1937 combination, ± 2 db. spread from mean.

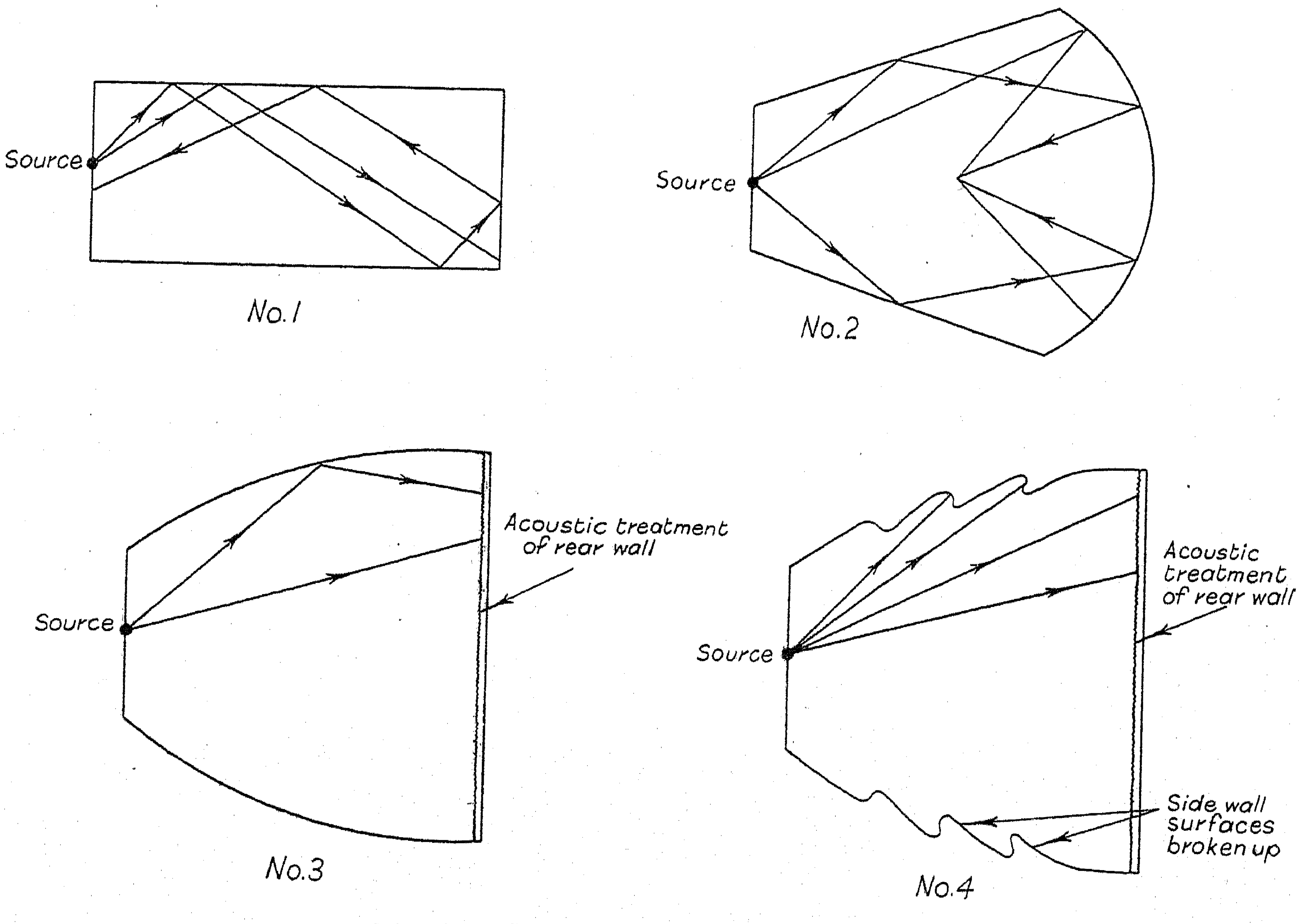

Source
No. 1
Source
No. 2
Source
Acoustic treatment of rear wall
No. 3
Source
Acoustic treatment of rear wall
Side wall surfaces broken up
No. 4

Fig. 14.—General trend of auditorium plans.

No. 1. Rectangular plan gave continuous cross-reflection.
No. 2. Curved rear wall tends to focus sound at one point.
No. 3. Some reflection from side walls.
No. 4. Scattered reflection towards source.

The importance of the correct reverberation time in the hall was realized from the first introduction of the sound film, but it was the practice to measure the reverberation at a fixed frequency, usually 500 cycles per sec., without reference to the fact that the reverberation-time/frequency characteristic was not linear. It was some years before suitable equipment was available for measuring the reverberation time at all frequencies. With improved methods of measurement and the greater demand, more suitable materials became available, and the question of accurate placing of the material was considered.

Modern halls are carefully proportioned to give the maximum seating capacity per cubic foot of auditorium, and it is common experience to find that the carpets, seats, and audience supply the majority of the sound absorbent required (Fig. 14). Additional sound-absorbing material to reduce serious first reflections (usually necessary on the back wall directly opposite the loud-speakers) must be sparingly used, and chosen to complement the characteristics of other absorbents. Wherever the auditorium or the decorations can be so designed as to assist in the reduction of the first reflections, this should be done, rather than rely upon acoustic treatment to obtain the required result.

THE TENDENCY OF FUTURE DEVELOPMENTS

It is evident that amplifiers and loud-speakers are in a more advanced state of development than the other links in the chain. Cinema acoustics is becoming better understood, but it is not yet possible to predict exactly with confidence the overall characteristics to be expected from a known equipment when installed in a new and untried auditorium.

The sound record itself is undoubtedly the place where improvement is most necessary. In particular, the standard of recorded quality on release prints should be brought nearer to the faithfulness which can now be obtained under carefully-controlled laboratory conditions. Whether this required improvement will be brought about by the general adoption of push-pull methods is a moot point. It seems possible that a similar improvement might be obtained by advances in the photographic materials and technique, coupled with an intensive development in the associated electro-optical components. In this connection the scanning system in the reproducer is not free from suspicion. A possible compromise may be provided by the general adoption of push-pull recording in the studios, assisted by the aforementioned developments aiding the re-recording of the sound to conventional tracks for general release.

The one link in the chain of faithful sound reproduction which is entirely missing is concerned with binaural listening. A normal person hearing original sound is able to locate the position of the source in space by virtue of the fact that the ears receive the sound in two components which differ slightly in phase, frequency characteristic, and amplitude. When sound is recorded and reproduced on a single channel this effect is lost and the listener is only able to judge the position of the reproducing loud-speaker and not the position of the original source with respect to the camera lens via which he views the scene.

A single-channel system can only be true for an observer who was born and has always lived with the use of one ear. It is only true in this case if reproduction is heard with a headphone.

For a normal listener the binaural effect can be obtained with a 2-channel system if headphones are worn, and for faithful results the two microphones must be placed at the ends of ear passages in a model of the observer's head.

When we attempt to reproduce sounds in the cinema the conditions are still further modified. In the first place, each member of the audience looking at the picture expects the sound to be reproduced at the screen as though the screen were at the sound source. Secondly, the acoustic properties of the hall add their own coloration to the sound in its passage between loud-speaker and listener.

One possible method which has given promising experimental results is to use three completely separated channels. The three microphones are placed round the source, and the loud-speakers are placed in similar relative positions. Movements of the source within the range of the microphones are thus accompanied by similar movements of the source image at the screen. Certain obvious difficulties such as the need for multiple sound records on the film, the varying acoustic conditions of the studio and the auditorium, and the limitations of a 2-dimensional screen, prevent the rapid growth of this development. It is, however, conceivable that we shall one day have binaural sound reproduction to complement stereoscopic and true-colour pictures.

In conclusion, I wish to express my thanks to the directors of the British Thomson-Houston Co., Ltd., for permission to publish many of the details embodied in this Address; to Mr. H. Warren, for the loan of the equipment used in the demonstration; and to my colleagues, Mr. G. S. Lucas, Mr. S. R. Eade, and Mr. J. Moir, for information which they kindly supplied.

METER AND INSTRUMENT SECTION: CHAIRMAN'S ADDRESS

By H. COBDEN TURNER, Member.

(*Address delivered* 5*th November*, 1937.)

First I want to thank you for having conferred this great honour on me of electing me as your Chairman for the ensuing year. It will be my earnest endeavour to carry out the duties to your satisfaction, and to follow the good example of those who have preceded me in this chair.

This Section was founded in 1928. At that time it had 114 members, whereas it now has 690. One feels that there must be many budding Kelvins amongst them, and I do hope that we shall find every month at our meetings fresh speakers, including some who have never spoken in public before. After all, one of the primary objects of our meetings is the exchange of technical knowledge, and to be a real exchange it is imperative that all shall contribute.

I have decided to divide my Address into the following Sections:—

(1) The reason for instruments.
(2) Brief historical survey of instruments.
(3) The instrument engineer's due.
(4) The instrument engineer's contribution to scientific progress.

(1) THE REASON FOR INSTRUMENTS

This Section is a very short one. Lord Kelvin once said that no real progress can be made in any science until there are available accurate and convenient means of determining, measuring, and recording, the various phenomena associated therewith, and I am sure that this is sufficient justification and inspiration for the continuance of our calling.

(2) BRIEF HISTORICAL SURVEY OF INSTRUMENTS

In this Section I have thought it sufficient to mention the first of each type, followed by an indication of the various inventors who have improved the type and whose developments have led to the present-day instruments.

I have obtained from the Science Museum at South Kensington (and from our own Institution) a few examples of pioneer apparatus; these may be inspected at the close of the meeting.

The types of instruments which have persisted can be divided into four main sections:—

(*a*) Electrostatic.
(*b*) Electrochemical.
(*c*) Electrothermal.
(*d*) Electromagnetic.

Of these (*d*) is by far the most important.

I give below, in concise form, the history of these four types:—

Electrostatic

		Year
First electrostatic instrument was the pith-ball electroscope		1753
Developments were due to:—		
Henley	Pith-ball electrometer	1774
Coulomb	Torsion balance with compound mechanism. First quantitative instrument of this type	1777
Snow Harris	First attracted-disc electrometer	1834
Thomson (Lord Kelvin)	Absolute electrometer	1853
Addenbrooke	Electrostatic wattmeter	1884
Ayrton & Mather	Voltmeter (original of present pattern)	1890
Ayrton & Mather	Pivoted voltmeters	1895
Rayner & Paterson	Reflecting precision wattmeters, which are still in use at the N.P.L.	1913
Abraham	E.H.T. voltmeters	1913
Banner	Low-reading voltmeters	1931

Electrochemical

Probably the first was the electrolytic cell for decomposing liquids, made by Faraday in		1833
The developments were due to:—		
Edison	Zinc voltameter	1881
Rayleigh	Used silver and got such accurate results that his instrument was used for the determination of the international unit of current —the ampere	1884
Bastian	Supply meter	1897
Wright	Used mercury and made the forerunner of the present d.c. meter of this type	1900

Electrothermal

A. Thermo-e.m.f. type.

Principle discovered by Seebeck, but not used as an instrument for measurement		1821
Klemenčic	First application to an instrument	1891
Duddell	Suspended instrument, galvanometer type	1904

B. Expansion type.

Cardew	Hot-wire voltmeter	1883
Ayrton & Perry	Using sag of heated wire instead of longitudinal extension	1887
Fortescue	Suitable for frequencies up to 100 megacycles per sec.	1935

Electromagnetic (Moving Magnet)

Principle demonstrated by Oersted's compass .. 1820

Improvements due to:—		Year
Nobili	Astatic needle	1825
Pouillet	First quantitative, still used in experimental physics	1839
Thomson	Instrument used for first Atlantic signals	1858
Drysdale	Adapted for alternating current by tuning to natural period of vibration	1910

Electromagnetic (Moving Iron)

Earliest recorded instrument by Blyth 1882

Improvements were due to:—

Miller		1883
Ayrton & Perry	Direct-reading solenoid instrument	1883
Kapp		1883
Kelvin	Ampere gauge	1885
Nalder	Repulsion type	1885
Evershed	Attraction type	1887
Hastin & Benson		1888
Schering & Schmidt	Vibration galvanometer	1913

Electromagnetic (Electrodynamic)

Principle discovered by Ampère 1820

Improvements were due to:—

British Association	Bifilar suspended type	1846
Joule	Current balance	1866
Siemens	Dynamometer	1877
Kelvin	Ampere balance	1883
Heap & Smith	Induction wattmeter	1901
Duddell & Mather	Precision null-pattern instrument with astatic coils	1901
Drysdale	Polyphase instrument	1901
Sumpner	Iron-cored wattmeter	1904
Moullin	Instrument suitable for radio-frequency currents	1930

Electromagnetic (Induction)

Ferraris suggested first instrument 1885

Improvements were due to:—

Elihu Thomson	Discovered " repulsion effect "	1887
Shallenberger	Used principle for house-service ampere-hour meters	1888
Wright	Shifting field produced by shaded poles	1889
Ockenden	Sub-standard instruments, shunted field	1927
Lipman	Sub-standard instruments, transformer effect	1927

Electromagnetic (Moving Coil)

Oersted's apparatus showed the principle 1820

Improvements were due to:—		Year
Varley	First pivoted instrument	1856
Kelvin	Used a suspended coil	1870
D'Arsonval	Reflecting instrument, rectangular coil	1882
Weston	Present design	1892
Davies	Special magnet poles giving a scale length of about 300°	1893

Earlier writers on instruments were unanimous in their statements that moving-coil instruments would be of no use for a.c. work, and yet to-day this use represents one of the largest fields of application, owing, of course, to the rectifiers now available.

On their first introduction to instrument makers about 10 years ago, rectifiers were rightly treated cautiously because at that time there was insufficient information regarding their life and constancy. Only the electronic types, utilizing the semi-conductors selenium and copper oxide, have survived the test of time, and can now be relied upon to give good accuracy and constancy. Some difficulty was experienced in the earlier stages owing to the high temperature coefficient of these rectifiers, especially the copper-oxide type, but compensation methods have been evolved which reduce this error to insignificance even for extreme temperature conditions.

These rectifier instruments supplied a demand which previously could not be met by compact, portable instruments; namely for the measurement of small a.c. voltages with minimum power consumption. A further important application was the measurement of current and voltage for frequencies up to 5 or 10 kilocycles. This led to an investigation of the frequency errors which occur at the higher frequencies mentioned, and this caused the production of special rectifiers of small capacitance, by means of which it is possible to extend the use of these rectifier instruments into the radio-frequency field. The rectified current from these low-capacitance rectifiers is adequate for operating a moving-coil instrument, and so by this means voltmeters are made for use on frequencies of over 1 megacycle. Such an instrument has wide applications not only for radio measurements but also for the new developments in telephony using coaxial cables, in which the frequency range extends up to 1 or 2 megacycles.

For the measurement of current the rectifier instrument has in the past been limited to the current-carrying capacity of the rectifier, which in turn is limited by the upper frequency which is to be measured. Thus the full-scale current has been either 1 or 10 milliamperes for tone-frequency applications. By using the well-known technique of the current transformer it is possible not only to increase the current range appreciably but also to limit that ubiquitous source of error at high frequencies—skin effect. The step-down ratio of the transformer is arranged to limit the secondary current to a value at which the skin-effect error is negligible. In this way high-frequency ammeters reading up to 10 or more amperes can be made to give accurate readings up to short-wave frequencies of 50 megacycles.

The core of the transformer is of very thin nickel alloy stampings for frequencies up to about 5 megacycles, and of magnetic dust for higher frequencies. The instrument is of special importance for the measurement of the aerial current of short-wave transmitters, as the aerial can be threaded through the centre of the toroidal transformer.

The use of a step-down transformer as mentioned above has also shown the way to the use of thermocouple instruments for larger currents at radio frequencies, by the same process of reducing the skin effect introduced at higher frequencies when the heater wire is made of larger section for heavier currents. Now, the current can be stepped down to the desired value for the most accurate results.

Thus the thermocouple instrument will continue to find important application for laboratory use because of its high accuracy, while the rectifier instrument may replace it for portable and commercial work where robustness, overload capacity, and good scale shape, are demanded.

Still smaller power consumption is possible when the rectifier is of the thermionic type. In this group both voltmeters and ammeters have been produced and the advantages claimed are that a wide frequency range is possible with negligible power consumption and extremely small capacitance. This group of instruments has recently emerged from the laboratory to the commercial field, and is now made in various portable types in self-contained cases. Whereas the original designs were supplied from an external battery, many valve voltmeters are operated from a.c. mains and contain their own stabilizing equipment. Special thermionic valves are made for these instruments, in which the grid and its leads are isolated from the other electrodes to minimize self-capacitance. While such instruments must necessarily be more expensive because of their complex construction, they are important for accurate voltage measurement at all frequencies above the power-frequency range.

(3) THE INSTRUMENT ENGINEER'S DUE

Previous speakers have commented on the fact that the average engineer takes instruments for granted—just as he takes pliers and screwdrivers—and never stops to consider the meticulous care which has gone to produce the results on which he relies for the furthering of his designs. Professors and lecturers have told us that at technical colleges and schools the students are generally not attracted by the prospect of studying instruments, and in commerce the same thing is exemplified by the fact that the instrument department is frequently, in large firms, a sub-department of the motor or transformer or other section.

To some extent this is due to the reverence for size which exists in all of us. Blank and Co. will photograph, paragraph, and advertise, the fact that they have just completed the largest alternator or the largest transformer, but will probably never deem it worthy of mention that their instrument department has just made an instrument so sensitive that it absorbs from the circuit only one-millionth part of the load which it so accurately measures.

Now, however, owing to the rapid improvement in instrument technique and the larger circle of knowledge which is required to produce the optimum design for the multifarious essential parts of an instrument, e.g. magnet steel with the highest coercive force, springs which never fatigue, pivots and jewels which never wear, dials which never fade, insulating materials which change not, and metals which mutually correct each other's temperature variations, the instrument designer has rightly become, in many firms, the referee in technical matters for many other sections of the works.

Someone, I believe in America, has defined a scientist as a man who can make two blades of grass grow where before was only one, and an engineer as one who can do for one penny what others can do for twopence. By these standards, too, an instrument maker can claim to be both—for with a small supply of copper and steel and iron, a little aluminium with a touch of silk and bakelite, of which the material value is probably one or two shillings, he makes a masterpiece which can produce a manifold return for its owner.

A proof of this is the penetration of electrical instruments into industries quite unconnected with electrical engineering. Indeed, there is nowadays a growing demand for electrical instruments in chemical, metallurgical, textile, paper-making, and other industries, some of which have hitherto been accustomed to methods which were not always scientific, such as the " rule of thumb " or judgment of the eye.

Two outstanding examples of the advantageous substitution of electrical systems of measurement for the above methods are temperature measurement and the measurement of illumination, to which I shall refer shortly.

Another important advance in instrument technique, which has redounded to the advantage of our industry, is the tendency and facility to make instruments, for all possible purposes, direct-reading. While this has sometimes been criticized because of possible errors in calibration, it is of incalculable value to the user of such instruments.

Another fairly recent achievement is the provision of special scale shapes other than those inherent in the design. Special open scales for such purposes as the reading of mains-voltage fluctuations have been general for some time, and various methods have been adopted for obtaining approximately linear scales from systems operating on a square law. Recently there has been a greatly increased demand for instruments to measure sound and light; the former for the communication and aural entertainment industries, and the latter for all types of lighting measurement, using photocells. Since the appreciation of the eye for light and of the ear for sound is on a logarithmic basis, it is desirable to use logarithmic scales in the measurement of those quantities.

The use of high-frequency currents for sundry special measurements is still in its infancy, and it is only during the last few years that high frequencies have been applied to measurements outside the well-known telecommunications field. High-frequency currents can be used for measuring dielectric materials with the same facility as direct current can be used to measure conducting materials. But whereas the latter apparatus can be operated from a dry battery or from supply mains, the high-frequency currents must be generated in, or associated with, the instrument. Fortunately, by adapting the recent technique of radio receivers, it is possible to make an oscillator driven from a.c. mains, and giving constant output over a wide range of frequencies, which can be built in a very small space. The remainder of the essential parts of such equipment consist of a bridge, a resonant circuit, and a detector, the latter being either of the valve-voltmeter type or of the metal-rectifier instrument type. Of these circuits, the resonant type with built-in voltmeter has much to recommend it.

Typical examples are the " L-meter " for the direct measurement of inductance and the " C-meter " for the direct measurement of capacitance; in the latter a fixed standard high-grade inductance is incorporated in the apparatus, and in the former a capacitance standard is provided. The tuning condenser of the oscillator can be calibrated directly in the units which it is desired to measure, the reading being taken by altering the tuning condenser until resonance is indicated on the valve-voltmeter instrument.

By modifying the circuit slightly and calibrating the valve-voltmeter instrument in suitable units, it is possible to make similar equipment for the direct reading of losses in either inductances or capacitances. The instrument for the measurement of the $\omega L/R$ value of a coil directly has been known to radio manufacturers for some years as a " Q-meter " and this gives the " goodness factor " of the coil, which is approximately the inverse of the power factor. With a fixed inductance coil such an instrument is also useful for the measurement of the properties of magnetic cores at high frequencies.

By the use of equipment for the direct measurement of the losses or power factor of a capacitance, in which special holders constituting condensers with fixed plates can contain samples of solid or liquid dielectrics, it is possible to obtain, rapidly, useful data regarding most substances which come into the category of insulators. Such tests are obviously important for the materials which are to be used for the construction of condensers, or those which are to be placed under electrostatic stress. There is also a field outside the electrical industry for such equipment for the measurement of the losses of such materials as oils, liquids, fats, mouldings, and synthetic products. Readings from a loss-meter on such products form a very useful guide to their purity.

Similarly tests can be made with the C-meter on these products to give their dielectric constant.

Much work has been done on this subject, and it is considered that here is a new field for the use of electrical measuring equipment.

(4) THE INSTRUMENT ENGINEER'S CONTRIBUTION TO SCIENTIFIC PROGRESS

In this Section I shall be able to deal a little more fully with the subject of the utilization of electrical instruments for purposes of measurement in systems not directly connected with electricity.

The most straightforward instruments of this type are those employing means for converting the energy to be measured directly into electrical energy.

Measurement of Temperature.

The measuring of temperature was the first important application of this type. Two methods are used—one in which a thermocouple is connected to a moving-coil millivoltmeter. This type of pyrometer, in which the instrument is calibrated direct in temperature, has been standardized for many purposes for several years, and the chief recent developments consist of the simplification of the apparatus. At first the indicator was of the unipivot type in order to attain the required sensitivity, but recently the more sensitive types of miniature double-pivot instruments have been used with success. These instruments can be incorporated in a rigid case with the enclosed thermocouple, making an extremely compact equivalent of the well-known mercury thermometer.

The other is the resistance method, using a special Wheatstone bridge in which a wire which changes in resistance with temperature forms one arm of the bridge. The resistance wire is calibrated at three known temperatures, and by measurement of its resistance its temperature is known at these and intermediate points. The readings of the calibrated indicator vary with the amount of out-of-balance of the bridge.

Measurement of Light.

Another of these simple " direct conversion type " instruments is the photo-electric cell series for the measurement of light in all its aspects. The development of the so-called " rectifier " cell by Lange in 1930 has introduced many lines of development to the instrument designer, of which so far we have only seen the beginning. The illumination meter, already mentioned, is the most direct application of this type of photocell, and for this purpose very sensitive moving-coil instruments are required. The average selenium cell will give an output of about 100 to 150 microamperes for an illumination of 50 foot-candles into a resistance of 300 ohms, or a power output of 30 milliwatts. This gives adequate sensitivity for the measurement of artificial light in buildings. With suitable screens to limit the light, similar instruments can be made for daylight measurement, and here the use of a logarithmic scale, referred to above, is specially applicable.

A direct result of this development is the exposure meter, used by an increasing number of photographers, where the light is registered on selenium photocells and by a simple turning of a rotary scale the correct exposure for any desired aperture and speed number of plate is obtained.

Measurement of Colour and Gloss.

The photocell and its associated equipment are capable of adaptation for the equivalent of certain well-known electrical circuits such as the bridge, and this is very useful in overcoming the effect of illumination variations. Two matched photocells illuminated from a single lamp arranged in bridge formation with a sensitive d.c. instrument in the conventional detector position enable the direct comparison of translucent liquids or materials to be made. Such instruments have wide applications for industrial comparison purposes, in which a manufacturer wishes to keep his products uniform by comparing them with his own standards. They are also being made for the comparison of the reflection properties of surfaces such as of paper, tiles, cloth, etc.

Measurement of Speed of Moving Body.

Angular velocity is measured by causing a small dynamo to revolve at a speed proportionate to the speed of the rotating body. The voltage generated is indicated on a voltmeter, usually marked in revolutions per minute. Linear velocity may be indicated by rolling a wheel of known perimeter, fixed to the dynamo shaft, on the surface along which the body moves.

Measurement of Sound.

The measurement of sound by direct electrical methods will soon perhaps be required as much as the measurement of light, thanks to the present crusade against noise in industry, transport, and everyday life generally. However, the technical problems are much more complex because of the complicated nature of sound and the lack of agreement on the definition of noise. Instrument makers have had to produce simple, small, and compact microphones, preferably of the self-generating type, giving uniform output over the aural range, which can be built into an instrument calibrated directly in phons.

Measurement of Thickness.

The well-known mechanical micrometer operating on a screw-thread principle is cheap, accurate, and reliable, for stationary samples and where both sides of the sample are available and not yielding. For moving materials or composite layers, the old methods of measurement are either difficult or impossible.

An electric micrometer for the measurement of the thickness of metal foil and sheet during rolling is very useful for controlling the uniformity of thickness; the earlier method was either skilled guesswork or the use of an ordinary mechanical micrometer on the foil when the rolling was stopped—often after the thickness limits had been exceeded. The new apparatus works on the principle of the screening effect of metals at high frequencies. A local mains-operated oscillator feeds current of the order of 20 to 100 kc. per sec. (dependent on the metal and actual thickness to be measured) to a coil fixed just above the metal foil. A similar coil below the foil has current induced in it to an extent dependent on the thickness of the foil. By using a bridge circuit and balancing this current against a known standard, thickness can be indicated or calibrated on a moving-coil instrument.

This method of thickness measurement has the great advantage that there is no mechanical contact with the metal. If the latter is covered in grease or non-conducting material such as paper or paint, there is no error introduced thereby.

There are other cases of thickness measurement, many for materials of non-metallic type, for which accurate and quick instruments are required. A method employing the use of a miniature transformer with an air-gap has already been recently described by W. H. Tait in the *Journal of Scientific Instruments*. This was primarily produced for the measurement of the thickness of tinplate in which a very thin layer of tin is coated on to a base of sheet iron. A U-shaped transformer, in one limb of which is the primary, fed from a.c. mains, is so placed that the magnetic circuit of the U is closed through the tinplate. The secondary is connected to a rectifier instrument, and it will be seen that the transfer of energy to the instrument will depend on the thickness of the non-magnetic coating. The instrument can therefore be calibrated directly in thousandths of an inch or other suitable units.

Measurement of Weight.

A continuous record of the change in weight with time of a substance is obtained automatically by means of the Oden–Keen balance. The apparatus consists of a sensitive chemical balance fitted with contacts, associated with a modified Callendar recorder. The material under test is suspended from one pan of the balance and is counterbalanced partly by metal pellets and partly by the pull of a solenoid and magnet. When the material changes in weight the beam is deflected very slightly and a contact is made. A circuit on the recorder is thus energized, with the result that the recorder pen moves. This movement not only causes a record to be made but also changes the current in the solenoid on the balance and restores the beam to the neutral position, where it remains until a further change occurs.

Measurement of Fatigue in Metal.

Another example of application of electrical apparatus for measurement purposes outside the electrical industry is fatigue testing for metals. The old-established method of static testing of metal bars and pieces has only met a part of the need of the designer of the modern high-speed internal-combustion engines. Such men require to know under what conditions of stress-reversals a metal will fatigue. A valve oscillator giving variable frequency is used to vibrate test pieces of metal by electromagnetic means at their resonant frequency. In a particular instance, samples which vibrate at 200 to 300 cycles per sec. have been chosen. The sample is thus subjected to fatigue of about a million reversals per hour, many times faster than is possible by mechanical means.

There is a tendency in such tests of materials to avoid the test to destruction in favour of continuously-applied tests under various working conditions and recording the various changes that take place on the material. The electrical recorder with several pens is very useful here, and it has recently been applied to the testing of materials and components to be used under high-voltage conditions.

Measurement of Depth.

A float controlled by the depth causes a wheel to turn as it moves. The wheel shaft carries an actuating gear which traverses a copper sleeve along an iron-cored centre-tapped choke. A rectifier two-coil ohmmeter is connected to the three terminals of the choke. Differences of impedance in the two halves of the choke, produced by the movement, result in differences of current in the windings of the two-coil ohmmeter. The scale of the ohmmeter is marked in appropriate units.

Measurement of Impurities in Mine Atmospheres.

A mine-gas detector consists of a Wheatstone bridge having four platinum-wire arms, two opposite ones of which are exposed, the other two being shielded. The bridge is enclosed in a gauze shield in a similar manner to a miner's safety lamp. The wires are heated to a cherry-red by a self-contained battery. The instrument, which indicates the degree of out-of-balance, is first brought to zero by pumping ordinary air. A test is then made in the mine. An inflammable gas present burns on the hot wire, thus causing an increase in the temperature and resistance of the wire, resulting in a deflection which varies with the amount of inflammable gas present.

Measurement of pH.

Accurate measurements of the relative acidity or alkalinity of solutions or viscous materials are best carried out by determining the hydrogen-ion content, known as the pH value.

An apparatus for this purpose consists of a box fitted with switches, adjusting rheostats, a pointer galvanometer, terminals, and a thermionic valve.

Small voltages generated in electrodes in the solutions are balanced against a Weston standard cell, using the valve as the sensitive detector. Since a null method is employed the accuracy is independent of the resistance of the electrode. Adjustments are provided for temperature correction. Continuous records may be obtained by using a recorder in place of the pH meter.

Measurement of Earth Vibrations.

The present-day seismograph is also an electrical instrument, in which a pendulum is free to oscillate round a nearly vertical axis but is damped by the usual eddy-current method. A coil mounted near one end of the pendulum can move in the gap of a permanent magnet; the coil ends are connected to a moving-coil galvanometer which is critically damped. For recording purposes a reflecting galvanometer is used in conjunction with a photographic drum recorder. To indicate or record the vertical component, the pendulum moves about a horizontal axis and is counterbalanced by a helical spring. On the occurrence of a vibration the supporting frame moves with the earth, the heavy pendulum remaining nearly stationary. The relative movement of the coil in the gap results in galvanometer deflections which follow the earth movements. By using one vertical and two horizontal components, complete records of an earthquake can be obtained.

Measurement of Flow.

This is achieved by means of a Venturi orifice which is connected to a mercury U-tube. Alteration of pressure causes variation in the height of the mercury column, thus disturbing a cast-iron float which, through a link-and-crank mechanism, transmits the motion to a gland spindle. A contact arm attached to the outer end of the spindle moves over a resistance and controls the indication of a moving-coil voltmeter. Variations of supply voltage are compensated for by means of a barretter.

Measurement of the Brightness of Road Surfaces.

For determining the brightness of street surfaces, an instrument has been devised in which a small metal-filament lamp supplied by a self-contained torch battery illuminates a translucent screen in such a way that one end of the screen is brighter than the other. A glass plate is silvered in small patches in a row and is mounted at an angle with the screen. When the street surface is viewed through the apparatus, images of the screen, graduated in brightness, are seen superimposed on the street surface, and the value of the spot equal to the surface brightness may be read against a scale.

An important part of the instrument is the voltmeter by which the lamp brightness is standardized at the required range.

Measurement of Viscosity.

An instrument primarily for determining the pressure coefficient of viscosity of liquids, and particularly of the mud mixtures used in the boring of oil wells, has been devised. The method consists in measuring the velocity of fall, in a tube, of a cylindrical sinker with spherical ends, the tube being filled with the liquid under investigation, at the required pressure. The sinker carries a small cobalt magnet, and around the tube are four coils equally spaced 7·5 mm. apart, connected in series to a small string galvanometer. As the sinker passes through each coil the galvanometer is deflected, these deflections being recorded photographically by a falling-plate camera. From the record the velocity can be obtained, and by a formula due to Lawaczeck the coefficient of viscosity can be calculated.

In conclusion, I hope that I have, albeit very inadequately, indicated that for the instrument engineer there is a limitless field of progress before him full of interesting work, where his already proved ability for taking pains will bring ample reward, not necessarily financial, but, what is far more important, in the sure and certain knowledge that his works will materially assist in the forward march of scientific progress where, more than ever before, the electrical instrument, be it moving-coil or microphone, is every day finding new work to do.

TRANSMISSION SECTION: CHAIRMAN'S ADDRESS

By J. L. EVE, Member.

"PROGRESS IN OVERHEAD TRANSMISSION LINES"

(*Address delivered* 17*th November*, 1937.)

It is my pleasant duty, in taking over the chair, to say how much I appreciate the honour that has been conferred upon me. I am glad to see the steady increase in our membership to over 1 670.

The recent rapid growth of the electrical industry in Great Britain can, in part, be attributed to the use of overhead transmission lines, both for trunk mains and rural distribution, and it is largely the responsibility of this Section to maintain the high standard of construction that has been reached by the progressive endeavour of members of this Institution.

Now that the main Grid Scheme is complete it would seem opportune to review the progress made, and I propose, therefore, to put before you a few particulars showing the various stages of development from the early pioneer days to the present time.

To give a complete history of the industry would take more time than is available now, so that I am forced to select only the prominent features of the subject.

This country was one of the first to make use of electricity for lighting and power, but transmission by means of overhead lines did not find general favour here at the outset. This is in contrast to the other industrial countries of the world and can be understood by consideration of the means available for the generation of power.

Fifty years ago in America and on the Continent in most instances the current was supplied from hydro-electric power plants which, being situated at the site of water power, were often some considerable distance from thickly-populated centres. The distances thus created between the generating stations and the consumers gave rise to the necessity for high-voltage transmission, and on investigation it was found that overhead transmission was a more economic proposition than the use of underground cables. Lines working at pressures of 10 000 and 20 000 volts were in operation as far back as the early 'nineties of last century.

On the other hand, in this country at that time coal was used for the generation of electric power, and engineers were able to choose sites for power stations in the densely populated areas, so as to reduce the distance of distribution as much as possible.

It follows, then, that the earliest transmission lines erected in this country were solely for the purposes of local distribution, and as far as I have been able to ascertain the first line was erected as far back as 1887 and was situated in the West End of London. The power station was in the basement of the Grosvenor Galleries in Bond Street, from whence supply was given as far away as Regent's Park, Hyde Park Corner, the Adelphi, and the Oxford Music Hall.

The supply was given at 2 500 volts, single-phase, 85 cycles, and was transmitted by means of an overhead line consisting of two vulcanized-rubber-insulated conductors suspended from a steel catenary by means of rawhide hangers. This catenary wire was in turn supported on porcelain insulators attached to wooden poles which were erected on the housetops at convenient positions.

The individual consumers were supplied by tappings from the main conductor, the tapping wires being taken through the roof in porcelain tubes down to the basement of the house, where a step-down transformer was situated.

This line remained in satisfactory service until the power station was destroyed by fire some 4 or 5 years later.

This seems to be an isolated instance, however, and in the next 12 years or so very little progress was made with transmission lines. Prominent engineers did not encourage their use, and as an illustration I quote Sir William Preece, who, when reading a paper before The Institution in May, 1891, said: " I do not intend to discuss overhead wires. I consider them, for high-pressure electric light circuits, an abomination." There were, however, one or two colliery lines and private supply lines erected before the dawn of the present century. I believe that the first line which received the consent of the Board of Trade was erected in 1898, from Coopers Hill power station in Lancashire, but no real progress was made until 1904, which saw the inception of the hydro-electric power scheme in North Wales. In this connection there was erected one of the first 10 000-volt lines in this country.

This wood-pole line was erected in the mountainous district of North Wales, and in spite of the severe test to which any line must be subjected in that area the line is still giving good service, which is remarkable in view of the fact that it was constructed 33 years ago. The insulators, poles, and conductors, are still in excellent condition. It is interesting to note that oak cross-arms were used throughout this line.

From 1904 until 1919 the progress made in this particular industry was less rapid than might have been expected. This lack of progress had been wrongly attributed to the onerous regulations laid down by the Board of Trade, but it was, in fact, chiefly due to the great difficulty of obtaining the necessary wayleaves, and this situation was not eased until the passing of the

Electricity Act of 1919, Section 22 of which deals with the compulsory acquisition of wayleaves.

Various undertakings were, however, erecting lines, and examples of the work carried out during this period can still be seen.

The local authorities were able to dictate their own conditions for lines crossing roads, etc., and often insisted on most elaborate guarding arrangements. Cradle guards and even catenary suspension of the conductors were not unusual.

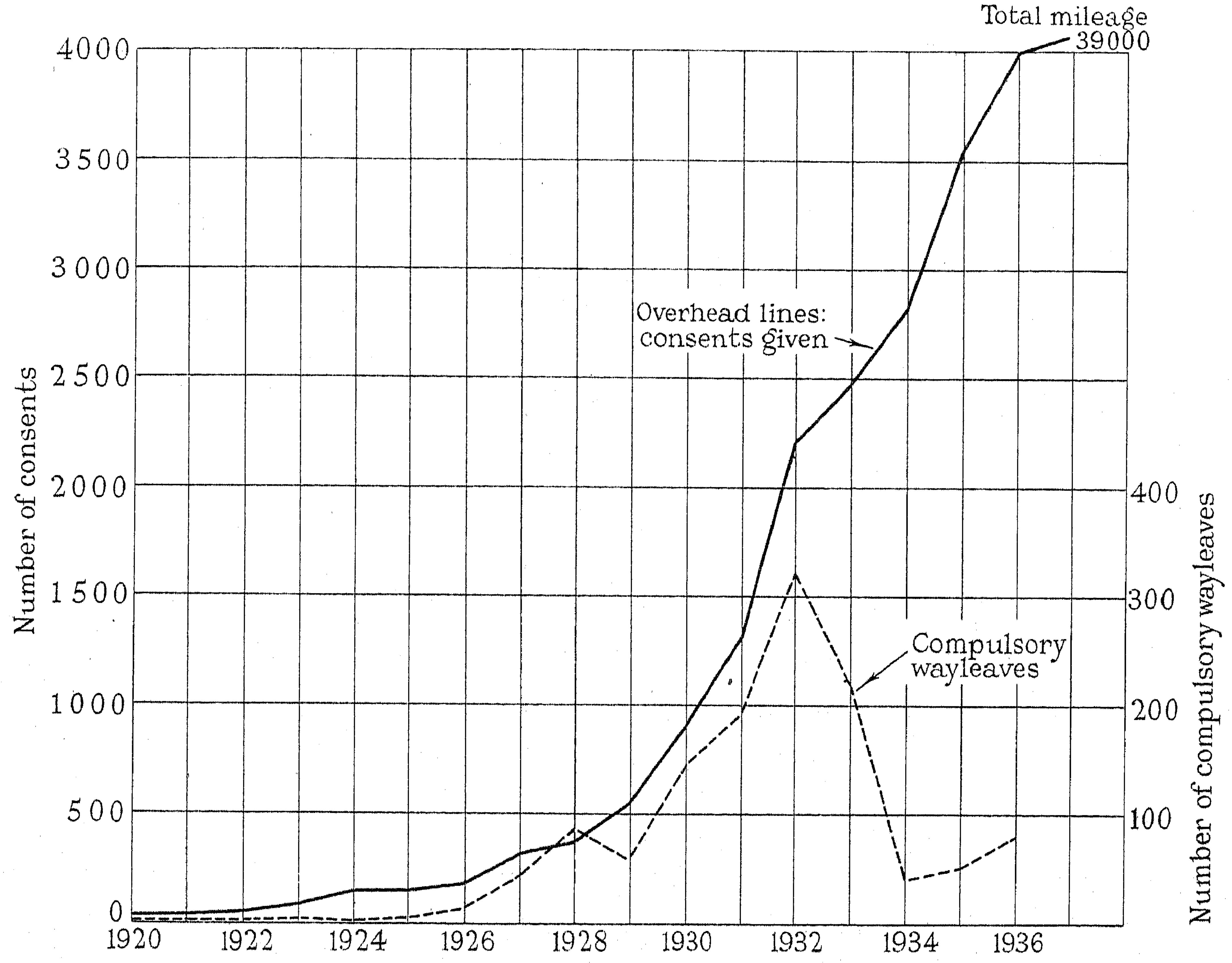
In Cornwall several lines were erected around 1910, and the line at Hayle is rather interesting. The towers are of a very light tubular lattice construction that has not, I think, been copied. These towers are still standing and are in excellent condition, notwithstanding the fact that a few of the foundations are regularly covered by the sea.

Some of the methods of dealing with Post Office crossings at that time are also of interest. The power conductors and telegraph lines were in some instances carried on the same structure, forming an ingenious guard, but this method has not appealed to the Post Office in recent years.

During the Great War engineers were forced to adopt unusual expedients. An 11-kV wood-pole line erected during that period was equipped with a variety of types of insulators and cross-arms, and pieces of motor-car tyres formed a novel type of bird-guard that proved quite successful.

In 1919, in addition to the passing of the Electricity Act, the old Regulations of the Board of Trade were revised by the Electricity Commissioners, whose formation took place in that year; and from then onwards transmission-line construction became more general. The graph on this page shows the number of consents granted during each of the last 16 years by the Commissioners and also the number of compulsory wayleaves obtained during the same period.

The formation of the Central Electricity Board in 1926, established to provide a National Grid over the country, was a great fillip to an already prosperous industry, and encouraged even more undertakings to launch out on schemes of their own.



Let us now consider the development that has taken place on the design side. When the first lines were erected at the end of last century, it was to be expected that the engineering methods and details used by the Post Office at the time would be closely followed, so that overhead-line engineers first used creosoted red fir poles for the supports. Similarly for the insulators; porcelain was adopted and the design was invariably a modification of the Post Office pin type. These were even used for end-strain positions when mounted on a swan-neck type of pin. The choice of conductors was very limited, and it is not surprising that copper, in the form of solid hard-drawn wire or a stranded construction, should have been the first choice.

Engineers were not long, however, in giving rein to their creative instincts, and many and varied designs soon appeared. Compound wood poles of the " H " type and " A " type had already been used by the Post Office engineers, and their increased strength appealed to the progressive-minded.

Various designs of double poles were advanced, but the only one that need be noted is the Rutter, named after its inventor. A somewhat similar twin pole has been available during more recent years and has been used quite extensively.

At this stage I must mention the exceedingly useful work undertaken by Mr. Wade, of testing wooden poles of all types and publishing the results. It is to be regretted that the results of tests of a similarly comprehensive nature on earth-type foundations for poles are not available, since even to-day rule-of-thumb appears to be the most satisfactory method of determining the necessity or otherwise of foundation blocks.

Progressive engineers were soon in the field with various designs of steel structures. Rolled-steel joists were experimented with, but, as can be expected, these did not find much favour. Tubular steel poles, however, offered many advantages over wooden poles. Their cost, and the inherent difficulty of attaching the insulators, were, I think, the chief reasons for their lack of general favour in this country. Both wooden and steel poles, however, are difficult to transport, so Mr. Kay successfully designed a pole composed of steel tubes and stranded steel guy-ropes. This pole, known as the " Kay " pole, was used quite considerably.

Various other forms of steel construction have also been proposed in an endeavour to find an economic alternative to the ubiquitous wood pole.

Bulb angles, either riveted or welded together, were used but have not been generally adopted. Some of the patented ideas that have been put forward, however, have met with some success.

The " P.B." pole, consisting of two special section channels braced together, should perhaps be considered as an offshoot of the lattice tower, but nevertheless it has stood the test of time as a substitute for the wood pole. The Bates pole, formed by slitting and expanding a rolled-steel joist, although used much on the other side of the Atlantic has hardly been used in this country at all. Amongst more recent entries into the field are the Fista pole, constructed by welding two channels and two plates into a box section, and the Adastra pole—a sectional oval steel-tube construction that was developed in Germany. This last pole is supplied in sections and it is claimed that transport and erection difficulties are materially decreased by its use.

Reinforced-concrete poles have received quite a measure of success in some cases. This type of support can be divided into two classes, the pre-cast pole and the spun pole. The former was the first in the field and many interesting examples are to be seen. Insufficient care in manufacture and poor-quality material are a grave source of danger to this type of structure, and poles can be seen in a very bad state of preservation. In some cases the concrete has not only cracked but has flaked away from the reinforcing rods, which have buckled and, when left bare, have corroded, with serious results. To-day, however, modern methods of manufacture have overcome such troubles and excellent poles can be obtained that are also very pleasing to the eye.

The spun pole was developed from the spun concrete pipe, and provided a concrete of a very dense character with an exceedingly smooth surface. It is rather surprising that only one high-tension line has been erected with this type of pole, although quite a number of tramway and lighting schemes have adopted them in the smaller sizes.

All the types of support to which I have referred are only suitable for moderately small loads necessitating the adoption of relatively short span lengths. This is a serious disadvantage when wayleaves are difficult to obtain, and is uneconomic when extra-high-voltage insulation is necessary. The lattice-steel tower has been the answer. The first designs were narrow-base masts riveted up complete at the steelworks and planted either direct in the ground or in concrete-block foundations. The difficulty of transport forced engineers, however, to abandon riveted joints in favour of bolted connections, and it soon became general practice to deliver the towers piece-small and carry out the assembly work on site. Incidentally, this enabled the members to be given a galvanized finish to delay the necessity of periodical painting. Attempts had been made to galvanize riveted towers after manufacture, but these were obviously unsuccessful owing to the pickle penetrating and remaining in the joints. It is on record that the towers on one line thus treated were returned to the works from the site and taken apart to be galvanized piecemeal.

Wide-base towers followed as a natural outcome of the heavier loadings caused by larger-section conductors and longer spans, and this type of construction was fostered by the Central Electricity Board's schemes. The Board's decision to subject all the towers designed for them to a mechanical type test did much to improve the technique of tower design, and showed the necessity for very careful consideration of details such as cross-arm and bracing connections. It is to be regretted that the results of these tests could not be published and made available for the general good of the industry.

The negotiation of difficult country and natural obstacles provides many interesting examples of engineering skill, and although it is well known to you all I must make reference to the biggest river crossing on the Central Electricity Board's system, viz. the Thames crossing at Dagenham. Other undertakings have also done work of this nature and, although on a smaller scale, the River Weaver crossing, with a span of 2 140 ft., is noteworthy.

The termination of several overhead lines at the generating station has presented difficulty in some cases, owing to the lack of space on which to erect the towers. This has been successfully overcome by carrying many circuits on one line of towers across the congested area. An example of this is to be seen at Stourport-on-Severn power station, where 6 circuits are carried on one line of towers. A somewhat similar scheme was adopted at Dunston-on-Tyne power station, where each tower carried 5 circuits.

At St. Helens, towers were erected straddling a railway track and form an interesting example of the ingenuity displayed in many directions.

Let us now turn to the question of conductors. As previously mentioned, copper was the first material used, but aluminium was also very early in the field. The old Northallerton Co. were the first to use this material for a public service line, in the form of solid conductors. Three sizes were adopted, namely $\frac{3}{8}$ in., $\frac{1}{2}$ in. and $\frac{3}{4}$ in. dia., and the lines operated at 230 volts (direct current). At first the conductors could only be supplied in short lengths of 25 to 30 yards, the lengths being joined together by a brass ferrule tapped Whitworth thread, the conductor ends being screwed likewise. The ferrule was well coated with a bituminous paint, and it is an amazing fact that this crude method of jointing gave no trouble, either mechanical or electrical. The line was taken down in 1932 after being in operation since 1899, and when the joints were examined they were found to be as new, no oxidation or electrolysis having taken place. On the other hand, electrolytic trouble was experienced with the copper binders at the insulators. This trouble was overcome by using aluminium binders.

Plain conductors are not suitable for other than short spans, so that conductors with a higher tensile strength had to be adopted when span lengths were increased. Phosphor-bronze, cadmium-copper, and other alloys, were natural developments, but steel-reinforced conductors were not used until later. The first steel-cored aluminium line was erected in 1923 over some quarries in the Midlands, but the first high-voltage line with 1 000-ft. spans on steel towers was not erected until 1927. This line runs along the sea coast, and, despite the proximity of cement works and the consequent pollution of the air, the conductors when last examined a short while ago were still in a perfect state of preservation.

During the last 10 years many thousands of miles of this class of composite conductor have been erected, including practically the whole of the C.E.B. system.

The reinforcing of copper conductors with a steel core has not been neglected; both copperweld and steel-cored copper strand have been used extensively.

The method of holding these reinforced conductors at end-strain positions has caused a great deal of controversy. Many types of clamp have been put forward, including the plain bolted type, the snail type, many types of cone fittings, and the compression clamp. The last named has, up to now, only been used on one complete line and for certain special work, and this is surprising in view of the advantages that it has to offer.

I shall be unable in this short Address to deal in any detail with the progress made in insulator design. It is sufficient to record that the research carried out in this department has kept pace with the increasing technical requirements of the industry. Do not imagine, however, that I think there are no more problems of insulator design to be solved, for this certainly is not the case.

One of the more recent developments is the use of post-type insulators which have been used to replace both pin and suspension insulators. In one district certain 33-kV lines running along the sea coast were originally fitted with 4-unit suspension sets, and supply was continually being interrupted by flash-overs caused by salt deposits. After a change-over had been made to post-type insulators the trouble ceased. With regard to insulating materials, porcelain has always been the most usual, but glass has met with some measure of success. One or two other compositions have been experimented with but have not been found very satisfactory.

I can sum up the whole question of the design of overhead lines by stating that during the last 15 years it has passed from guesswork to exactitude. The only difficulty of the designer to-day is in estimating the loadings that his structures, conductors, and insulators, will have to withstand, and making suitable allowance for the especial conditions likely to occur in any particular district. It is often the case that far too little consideration is given to this aspect of design, many engineers being content to design strictly to the Regulations, regardless of local conditions. Obviously, some conditions of loading are so rare that to guard against them would be uneconomic, so that the problem is one that requires more than a cursory investigation.

In conclusion, therefore, I think it would be advantageous to give a little attention to this matter and consider some of the conditions and difficulties that a transmission-line engineer should allow for in his designs.

Perhaps the most common cause of temporary failure, and certainly one of the easiest to guard against, is that of birds perching on the conductors and touching earthed metal. It is curious that birds do not perch on conductors working at voltages above 80 000.

Lightning is another source of interruption and one that is causing many engineers seriously to consider the provision of special forms of protection. Wood poles have on occasion been badly damaged by fire caused by lightning.

The severity of the weather conditions depends largely on the location of the route. Salt deposits are to be expected along the sea coast, and in low-lying country floods can be constant source of danger. Over moorlands, and in the mountains, snow and ice-loading sometimes occur to a much greater extent than is allowed for in the Commissioners' Regulations. Ice coatings up to 6 inches in diameter have actually been observed on more than one occasion in recent years.

More difficult to guard against is the danger of ground subsidence in districts where mine workings exist, but this can be avoided to some extent by careful investigations before the route is decided upon.

None of these troubles is impossible to overcome and there is no reason why every overhead line should not be erected to guard against them to the extent necessary to secure uninterrupted operation.

In conclusion, I should like to express my thanks for the kindness shown to me by many friends in the industry that has enabled me to prepare this Address.

WESTERN CENTRE: CHAIRMAN'S ADDRESS

By H. G. WEAVER, Member.

"MODERN APPLICATIONS OF ELECTRICITY IN STEELWORKS"

(*Address delivered at* CARDIFF, 11*th October*, 1937.)

Having been interested for many years in the applications of electric power in the heavy industries, which are of great importance to this district, I have thought it appropriate that my Address should be on that subject, more particularly as applied to ironworks and steelworks.

Furthermore, the subject is one which has been somewhat overlooked in the *Journal*, and, until recent months, in the technical Press of this country.

These omissions are somewhat surprising when it is realized that approximately 70 % of the total units sold by the supply authorities in this country are for industrial purposes, and more electric power is generated and used in this industry than in any other.

In recent years rapid developments have taken place in steel rolling-mills and their auxiliaries, and huge outputs are now obtained of material rolled with a precision which was previously thought impossible. It can be claimed that much of the success of these mills is due to the electrical engineer being able to meet the exacting requirements of the mill designers for drives which are reliable, accurate, and easily controlled, and which no other type of prime-mover could provide.

Some of the technical problems involved in the main drives, and also in the driving of the auxiliary plant, are of more than usual interest, and are rarely met with in other industries.

The power requirements of modern steelworks are much greater per ton of output than was the case even a few years ago, due to the fact that they include departments for converting, into highly finished material, a large proportion of the steel made, and the power consumption per ton increases very rapidly in the finishing processes. Also, a large amount of power is now used for melting and refining steel in electric furnaces, and for the heat treatment of steel. Increasing use is being made of the induction furnace, not only to make highly refined grades of steel, but to absorb the valuable scrap consisting of this class of steel, arising, in large steelworks, from broken rolls, shear blades, and the like.

The gases available from the coke ovens and blast furnaces can be used to generate power at a cost which compares favourably with that obtained from a super-power station, but it is of interest to note that two of the large steelworks in this district are taking large supplies from stations connected to the grid. The prices paid are no doubt much nearer to those usually paid by the Central Electricity Board for power which they purchase, than to the grid tariff.

Owing to the continuous nature of many of the processes in steelworks, reliability of power supply is of great importance, as serious disorganization and loss can be caused by a failure of only a few minutes, or even a momentary disturbance, if of some magnitude. When large shunt-wound motors are used, supplied from rotary convertors, special precautions are necessary to deal with reverse currents, which can be very severe under some conditions, when a momentary drop in the supply voltage occurs. The effects of a momentary disturbance in the supply appears to depend more on its duration that on its magnitude, and much attention is being given to the design of ultra-high-speed apparatus for clearing faults on large systems of supply in the minimum of time.

The outstanding feature of the main driving motors installed in recent years is the large proportion of d.c. machines. Large reversing mills for rolling ingots into blooms, or for producing heavy plates, are driven by d.c. motors of the single-armature or double-armature type. These motors have to reverse from full speed in one direction to full speed in the other direction in a few seconds, and peak outputs of 20 000 h.p. are not unusual. They are supplied from motor-generators fitted with heavy flywheels, and are controlled on the Ward–Leonard principle. The motors on these motor-generators are usually of the induction type, with their slip automatically controlled, to allow the set to drop in speed under load and thus enable the flywheel to reduce the peaks taken from the supply. The output capacity of the generators on these sets is frequently considerably greater than that of the motor driving them. In one interesting installation in this district, geared steam turbines have been used instead of motors to drive the generators, a flywheel also being used in this case.

The latest development in the control of this type of reversing-mill drive is a completely automatic system, which makes it impossible for the operator to do any damage or trip the main circuit-breaker and shut down the mill owing to careless handling. The peaks taken from the supply, and the rates of acceleration and deceleration, are automatically limited by specially designed exciters, and the control is much simplified.

Single-speed continuously-running motors are used to drive 3-high mills for rolling blooms or continuous (tandem) billet or sheet-bar mills. These motors are usually low-speed a.c. machines of the induction or synchronous type, with a normal rating of about 5 000 h.p. They have no special features, apart from their large dimensions.

The most interesting main drives are those met with in continuous (tandem) hot or cold rolling-mills, where separate sections of the mill, and in some cases each pair of rolls, are driven by a separate motor. As there are several mills of this type in this district, and large mills for rolling hot and cold strip are now being installed, some remarks on their electrical features may be of interest.

This type of mill was developed in America during a period when in that country there was considerable antipathy towards d.c. machines, and, where a variable-speed main drive was required, it was the practice to install a.c. motors of the induction type, the speed of which was controlled on the Scherbius or Kramer system. It is of interest to note that the first mill of the continuous type to be driven entirely by d.c. motors was installed in this district some 16 years ago.

When the product rolled is of such a length that the same piece of steel is in more than one pair of rolls at the same time, the speed of each pair of rolls concerned must have a correct ratio to each other at any instant, and, as this ratio varies with the size and section of the material being rolled and is continually subject to variation due to roll adjustments, wear of roll-neck bearings, and other causes, each motor must have a wide speed-range and be capable of fine speed adjustment. Special speed-control arrangements have been designed to obtain the fine adjustments necessary in some cases as mentioned later.

When a pair of rolls is so placed in the mill that the steel passing through them is not in any other pair of rolls at the same time, constant-speed motors can be used.

It is now standard practice to use a.c. motors for constant-speed drives, and d.c. motors for variable-speed drives.

The largest mill of this type yet installed is driven by a total of 15 000 h.p. of a.c. motors, and 27 350 h.p. of d.c. motors, for the main drives. Including the motor-generators, the total plant used in connection with the mill amounts to 50 000 kW, and the maximum demand is about 30 000 kW.

Owing to the layout of this type of mill, the driving motors have to be somewhat crowded together, and special precautions have to be taken to ventilate the machines and motor room, a problem which is not always easy to solve. A very large volume of cool, clean, air is required, and this is difficult to obtain in steelworks.

The d.c. motors used for these drives are shunt-wound, with commutating poles and compensating windings specially designed to give a flat speed characteristic from no load to full load, and capable of withstanding very heavy overloads.

When rolling hot strip in tandem mills, tension in the strip between each pair of rolls must be avoided, but some latitude in the speed control is allowable, as a vertical loop can be formed by the strip between pairs of rolls, and, within certain limits, this loop can be mechanically controlled. In the case of semi-continuous mills, some of the rolls are placed in tandem, and some parallel to each other, the steel forming a horizontal loop between the latter. In these cases more latitude is available, as the loops can be allowed to run out on the mill floor. Speed control of each motor is obtained by manually operated or motor-operated rheostats in series with the shunt field windings.

When rolling coils of cold strip in tandem mills, it is necessary to maintain a definite constant tension in the strip between the unwinding reel and first pair of rolls, between each pair of rolls, and between the last pair of rolls and the winding-up reel. This requires extremely close speed control, and automatic apparatus has now been developed for controlling the tension.

This apparatus is actuated by the strip itself passing over rollers placed at the points above mentioned. These rollers are supported on resilient bearing standards, and any motion of these standards varies the air-gap on transformers placed at each end, in such a manner that voltages are obtained which are directly proportional to the pressure on the roller. These voltages are used to operate regulators controlling the shunt fields of the motors and thus maintain the required tension constant, also to operate instruments, calibrated in pounds, to indicate the actual tension in both edges of the strip.

Tension in the strip between the unwinding reel and first pair of rolls is obtained by generating power from a dynamo driven by the reel.

The type of converting plant used to obtain the d.c. power required for continuous mills depends to a great extent on the operating conditions. Rotary convertors are the most efficient and are used when constant voltage is required, and it may be necessary to be able to start or stop any single motor. Expensive control gear is then necessary for each motor, and this usually consists of automatic contactor gear, remote-controlled from a convenient operating centre in the mill.

When motor-generators are used, advantage can be taken of the variable d.c. voltage obtainable, and the mill motors can be controlled on the Ward–Leonard principle, thus eliminating the more expensive control gear. This system has to be used when the operating conditions are such that it must be possible to accelerate, decelerate, stop, or start, mills with variable-speed drives during rolling, as the relative speeds of the motors must be maintained during these operations. Advantage can also be taken of the variable voltage to increase the inherent speed-range of the mill motors, and thus increase the range of product it is possible to roll. On the other hand, the efficiency of the motor generator is considerably lower than that of the rotary convertor.

The mercury-arc rectifier with grid-voltage control is now being used in some cases, but special precautions have to be taken where a regenerative voltage is likely to occur.

An interesting type of cold-rolling mill from the electrical point of view, which has been installed in this district, is a reversing mill for rolling steel strip in coils. The mill itself consists of a single stand of 4-high rolls with a reel placed at each side. The rolls and each reel are driven by separate motors. In operating the mill the coil of strip is placed on one reel and the outside end is threaded through the rolls and attached to the other reel. The rolls and both reels are then accelerated to the speed required for rolling, and as the end of the coil is approached the whole is decelerated to creeping speed, and then stopped with only the inside end of the coil left on the unwinding reel. The rolls are then screwed down to give the required reduction of thickness, and the mill and reels are run in the reverse direction for the next pass.

For reasons connected with rolling technique and the physical properties of the steel after rolling, it is necessary for the strip to be in a constant tension on both sides of the mill during rolling, and at standstill. The tension on either side must also be independently adjustable within wide limits, and maintained automatically, with very small variations, during acceleration, rolling, and deceleration. The motors are specially designed with the flywheel effect of the armatures as low as possible, as the effect of this on the tension during acceleration and deceleration has to be compensated for.

Owing to the fact that the diameter of the coil on the unwinding or entry side decreases as the coil is being rolled, the speed of the reel on that side must gradually increase, and the opposite is the case with the winding-up reel. The amount the strip is reduced in thickness by the pass will also affect the ratio of the speeds of the two reels.

The tension on the unwinding side is obtained by the strip driving this reel motor as a constant-current generator, feeding power through a booster into the main generator. The tension on the winding-up side is obtained by driving this reel motor with constant-current input. The tension in each case is directly proportional to the armature current, and the current required is kept constant by regulators of the vibrating-contact type, which operate through boosters in the shunt field circuits of the reel motors. When the mill is reversed after each pass, the functions of the reel motors are also reversed.

The d.c. motors driving both reels and rolls are shunt-wound and are supplied from a motor-generator, on the Ward–Leonard principle, and operated by automatic contactor gear controlled from either of two desks, one on each side of the mill. Smooth acceleration and deceleration is assured by motor-driven ganged rheostats in the various shunt fields, and the rate of each can be controlled from the desks. Other operations controlled from the desks include inching either reel, inching mill only, inching mill and either reel, inching mill and both reels, running mill and either reel, also adjusting the roll screw-downs, in either direction in each case.

Modern d.c. motors of all sizes have been found very satisfactory under the arduous conditions met with in steelworks, and manufacturers of these machines in this country can claim to have led other countries in the improvements which have been made in recent years. The old troubles with commutators and brush gear caused by mechanical defects have almost disappeared, owing to improved construction and " seasoning " of commutators, and the electrical defects have been overcome by neutralizing the distortion of the magnetic field under load, by means of commutating poles, and compensating windings in the pole-faces.

In some drives the r.m.s. value of the load may be quite small compared with the maximum load, and under these conditions the ability of d.c. machines to commutate very heavy overloads, and, in the case of a.c. machines, the maximum pull-out torque, may be of more importance than temperature-rise. It is necessary in these cases to give the manufacturers the fullest information regarding the duty cycle, to enable them to design the machine and control gear accordingly.

An example of a drive of this nature with which I am acquainted is that of a 10-h.p. shunt-wound d.c. motor which drives an auxiliary handling the whole output of a large mill. The motor has a speed of 3/1, and when operating at top speed it has to accelerate from standstill to full speed in 5 seconds, run at various speeds for 20 seconds, then decelerate to standstill in 5 seconds, this cycle being repeated continuously. Deceleration is first by regenerative braking, then by dynamic braking. Owing to the heavy flywheel effect of the part of the auxiliary which is driven, the current peak during both acceleration and deceleration is 10 times normal full load, but the r.m.s. value of the load cycle is much below the normal rating of the motor, and the temperature-rise is quite low.

Auxiliary machinery is very important in modern mills, and it must be appreciated that the failure of a motor or control gear of a few horse-power may cause the stoppage of a large plant and the loss of many tons of output. Frequently very special drives have to be designed, such as the one mentioned later.

For driving continuously-running constant-speed auxiliaries, a.c. motors are generally used, of the squirrel-cage type up to about 25 h.p., and of the slip-ring type for larger sizes. The various types of high-torque squirrel-cage motors now available make their application possible in many cases where formerly the slip-ring type had to be used. This type of motor is very suitable for steelworks, owing to its simplicity and robustness, and when totally enclosed, fan- or frame-cooled, with ball or roller bearings, they will run for long periods with very little attention.

Variable-speed continuously-running auxiliaries are usually driven by d.c. motors with shunt field control, and in these cases also the totally-enclosed, fan or frame-cooled type, with ball or roller bearings, is the most satisfactory.

Occasionally it is necessary for an auxiliary to be driven at a speed which synchronizes with that of a variable-speed main motor. One method used is to drive the auxiliary by an a.c. motor supplied from an alternator driven by the main motor concerned. Another method, when the main motor is a d.c. machine, is to supply the a.c. motor with alternating current taken from slip-rings fitted to the armature of the main motor, so that the latter acts partly as a rotary convertor. No starting gear is necessary, as the a.c. motor will start, stop, or reverse, in synchronism with the main motor. The a.c. motor is of course designed to work at a variable frequency in such cases.

For drives such as live rollers, tilting tables, and roll screwdowns, which are subject to very severe reversing duty, special steelworks-type a.c. and d.c. motors have been developed. They are totally enclosed, with split steel frames which enable the armature or rotor to be quickly removed, and the mechanical parts are very robust. The insulation used is usually mica and asbestos, and for hot situations, such as in close proximity to hot metal, pure mica is used.

In some recent installations live-roller tables have been designed with individual motors for each roller, where frequent starting and stopping is required. These motors have been specially developed for this duty and are direct-coupled to the roller. In some types the roller itself is also the rotor of the motor. Special insulation is used to withstand the high-temperature conditions under which they operate. The motors are supplied from variable-frequency motor-generators, and are designed to work at a low frequency to obtain the high torques required for acceleration, without very heavy starting currents. Owing to the absence of gearing a high efficiency is obtained, with low maintenance, and with this system of driving it is possible to arrange for the tables to work round curves if desired. It also has the advantage that the failure of one roller does not put the whole table out of commission.

Another type of a.c. motor of special construction is now being used for applications where the duty consists of frequent inching and reversing, such as sheet catcher gear. The machine has two stators, with two insulated squirrel-cage rotors on a common shaft, and by a cascade arrangement of connections the inertia of the rotors is reduced to a minimum, while retaining a suitable torque characteristic. The secondary stator is short-circuited through a resistance which is mounted on the outside of the machine. This resistance dissipates a large proportion of the heat generated by the electrical losses which are unavoidable with frequent reversals, and reduces the temperature-rise of the motor. A useful feature is the facility with which the characteristic can be altered, if desired, to meet varying conditions, by altering the value of the resistance. Such machines have to be capable of sustaining as many as 40 reversals per minute continuously, and make so few revolutions in either direction that they are really torque motors, rather than machines of a recognizable horse-power rating.

An example of a special drive for an important auxiliary installed in a steelworks in this district may be of interest. The drive is that of a shears for cutting hot steel blooms, up to 12 in. by 12-in. section. The motor is of the d.c. shunt-wound type, and is rated at 350–650 h.p., with a speed range of 300–900 r.p.m. It has to accelerate from standstill to 900 r.p.m. in $5\frac{1}{2}$ seconds, and decelerate from 900 r.p.m. to standstill in $2\frac{1}{2}$ seconds. Acceleration is by series resistance and field regulation, deceleration by regenerative and then dynamic braking, with final stopping in a predetermined position by solenoid braking. The duty specified is 5 individual cuts per minute, or 156 cuts per hour continuously. The control is by automatic contactor gear, with a simple switch for starting.

It is difficult to imagine a drive of this nature being possible at all, previous to the development of automatic contactor control gear and the improvements in d.c. machines.

Troubles with the older types of control gear were very frequent in steelworks, due to the very rough usage met with, and the introduction of magnetically-operated contactors solved many difficulties. It is the only type which can be made really foolproof, and not only to protect the motor concerned, but also itself, against damage caused by ill-usage. It also has the valuable feature that the main part of the gear can be housed in the most convenient position, where it cannot be tampered with, and it is only necessary to provide room for the push-buttons or master controllers at the operating positions. It can also be used to control a sequence of operations automatically, and there is an example of this application to a blast furnace in this district. The various materials are selected from the bunkers, weighed, hoisted to the furnace top, dumped on to the charging table, and fed into the furnace to a time sequence. All the motions are interlocked electrically and thus made foolproof.

In recent years the use of the photo-electric cell as a relay in conjunction with this type of control gear has increased the possibilities of automatic operation to an almost unlimited extent, and this elimination of the human element has resulted in considerable improvement in plant efficiency. One recent application is the automatic adjustment of the roll screwdowns in large mills to give the correct predetermined reduction of thickness at each pass.

There is an increasing tendency on the part of some manufacturers to make this type of control gear more complicated than is necessary, and the small parts too numerous and flimsy. It is not always appreciated that, for its successful operation, the proper functioning of a small auxiliary contact is as important as that of a main contact. It is also suggested to the research departments of the manufacturers that a really satisfactory type of high-resistance unit, of small current-carrying capacity, should be developed, to remove one of its weaknesses. The too frequent occurrence of surface leakage across bakelite insulation, between live parts at quite low voltages and with clean conditions, which suddenly develops into a short-circuit, is also a matter which appears to require investigation.

The engineer responsible for the satisfactory operation of electrical plant in industry, particularly where it is subject to rough usage and bad conditions, is in a position to discover weaknesses in design or construction of which the makers are perhaps not aware. Some of these faults may take months, or even longer, to develop and be of such a nature that they do not become apparent during the usual tests at the makers' works when new. Among such faults may be mentioned shaft fractures due to local fatigue of the metal, short life of bearings, gradual loss of oil from bearings or switchgear, excessive wear of commutators or slip-rings or brushes, unsuitability of insulation under certain conditions, and, equally important, lack of accessibility. The maintenance requirements due to trouble given by electrical plant depend to a great extent on its accessibility and the simplicity of its parts.

It is suggested that the staff of all large manufacturers should include an engineer whose duty would be to visit users of their plant to obtain criticisms of it, and, perhaps, suggestions for its improvement. There is still need for a closer liaison between the two interests concerned, which would be to their mutual advantage.

It has only been possible, in this short Address, to give a brief outline of the principal developments which have taken place in the applications of electric power in one of our most important industries, and of the associated technical problems that have been solved. It appears that similar advances have taken place in other large industries, but that too little space has been devoted in the pages of our *Journal* to this subject of industrial applications; and it is suggested in consequence that, in order that our members may derive the full benefit of the increase in scope and technique of electric power, greater attention to the subject should be paid in the papers presented before our Institution.

NORTH MIDLAND CENTRE: CHAIRMAN'S ADDRESS

By J. G. CRAVEN, Member.

"THE CONTRACTOR'S SPHERE OF ACTIVITIES IN THE ELECTRICAL INDUSTRY"

(ABSTRACT *of Address delivered at* LEEDS, *12th October*, 1937.)

As far as I have been able to trace, I am the first member of the electrical contracting and installation section of the industry to be elected Chairman of this Centre; and for this honour not only to myself, but also to the contracting section, I would express my grateful thanks. The honour you have accorded to me is a further definite help towards improving the status of the contracting and installation section, following on, as it does, the election last year of another contractor member as President of The Institution.

My remarks in this Address are in no way an attempt to show that a high degree of technical ability is essential to an electrical contractor, but that at least in designing and carrying out power and lighting installations, and in installing the innumerable electrical appliances which are available, particularly for industrial purposes, some degree of technical knowledge is essential.

One finds that for quite a considerable percentage of even large wiring installations, both power and lighting, a specification is not available, the design and layout being left entirely in the hands of the contractor.

It would be quite impossible for me to cover in detail the various branches of installation work, and I shall therefore confine my remarks to one or two sections.*

THE CONTRACTOR

It covers an enormous field of activity to state that the contractor or installation engineer is concerned with the installing of private generating plant, batteries, mains (underground and overhead), power and lighting wiring, in all classes of premises, and also with every conceivable current-consuming device.

I would say that, generally speaking, the contractor's work commences at the supply authority's terminals on the consumer's premises, and terminates at some form of current-consuming device; and it is his duty to his customers and the public to see that the supply, whether private or public, is efficiently harnessed by an installation complying, in the main, with the I.E.E. Regulations.

That it is not essential for an electrical installation to comply with any particular set of Regulations is certainly an enigma of the present electrical age, although considerable strides have been made during the last 4 or 5 years towards the general adoption of the I.E.E. Regulations for the Electrical Equipment of Buildings, and the day when these will be made compulsory appears now to be nearer than one could have hoped for only a short while ago.

It does not appear to be at all widely appreciated by the electrical industry that the contractor is daily installing somebody's manufactures, which will eventually be carrying current and utilizing it in some form or other, whether it be for motive power, lighting, heating, or some other current-consuming device.

Without doubt the utilization of electricity is of paramount importance to the supply authority, and no less to the manufacturer and contractor, and whether it be by a large industrial power plant, a lamp, a vacuum cleaner, or a wireless set, all three sections of the industry are affected.

Happily the day has gone by when the supply authority considered that power loads were the thing to go out for; and it is now realized that an electrical appliance taking only a few watts will, if used universally, result in a load of tens of thousands of kilowatts.

The figures published of 40 000–50 000 kW taken from the grid by wireless sets alone during special broadcasts of national interest show the importance of a load of this nature; and it is of interest to note that, during a recent broadcast from the United States in the early hours of the morning, the radio-set load was further considerably increased by the use of electric radiators.

One wonders whether at some time in the future it will be part of the supply authorities' business to stage the broadcasting of events of national interest, in order to dispose of additional units in off-peak hours.

The contractor owes a great debt to "wireless," in that it has resulted in thousands of small lighting installations in order that an all-mains set can be used, the urge to have a radio receiver having "sold" the lighting installation.

POWER INSTALLATIONS

With power installations where no unit exceeds 30 or 40 h.p., it is usual to carry out the wiring work with vulcanized-rubber cables in heavy-gauge screwed conduits, but in larger installations where heavy mains have to be run to switch or fuse distribution-boards, and from these to large motors, vulcanized-rubber cables and the conduits become excessive in size and cost. A glance at Tables 5, 6, 10, and 11, in the I.E.E. Regulations (10th Edition) will show the great advantage as regards size, and consequently cost, to be obtained by using paper-insulated cables for main and sub-main distribution, and for motor circuits in large industrial premises, particularly where long runs of cable are necessary.

When, in order to carry 150 amperes, a 0·25 sq. in. 3-core vulcanized-rubber cable is necessary, as against a 0·12 sq. in. 3-core paper-insulated lead-covered cable, the reduction in size and cost by using the latter will be readily appreciated. It should, however, be mentioned that, as a set-off against the saving, there is the additional cost of providing a suitable sealing box at each end of the cable, with the attendant additional labour required to trifurcate and to seal off with compound.

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* The author illustrated his remarks in the Address by a number of lantern slides showing various types of installations and installation work.

In practice, over a period of some 18 years, I have found single-wire armouring, left bright, on paper-insulated lead-covered cables, run in air in industrial premises, to give ample mechanical protection, and such cables in the larger sizes should be provided with " whipping wires " to prevent barrelling or bird-caging at bends. This type of cable presents a neat and clean appearance, and a double-wire armour, or serving, is only necessary in very exceptional circumstances.

It is of the greatest importance to note, when installing in factories paper-insulated lead-covered cables in air, that if it is found essential for the cable to enter and leave switchgear or fuseboards, etc., vertically from above, the cables should be " drained " by the manufacturers, otherwise whatever precautions are taken in bringing out the tails or cores of the cable to the terminals, and however hard a quality of compound be used for sealing, the oil in the cable will sooner or later percolate through into the switchgear or fuseboard.

Where the contractor has his own works it will be found very convenient and economical if he designs and makes the various types of cable racks, " J " hooks, hangers, etc., necessary for the running of armoured cables on walls and steel work such as roof trusses and stanchions.

For short cable-runs between starters and motors up to 50 or 60 h.p., vulcanized-rubber single-wire armoured cables will be found more economical than the paper-insulated type, as cable sealing-boxes and the necessary labour in connection with the same will be eliminated, only armour clamps on the starter and motor being required.

Armoured cables are also advantageous in that they give sufficient flexibility if a loop is left for the movement of the motor when fixed on slide rails. Where a conduit system is used, this necessitates leaving this short of the motor, and inserting flexible metallic tubing between it and the motor terminal box, and, however suitably bonded this may be, the Home Office Regulations do not accept the flexible tube as an efficient earth.

Modern factory construction is providing the contractor with additional difficulties in connection with designing distribution layouts, as the tendency now in large factories is to eliminate as far as possible steel stanchions, which, heretofore, have provided the contractor with excellent fixing positions for central distributing points in connection with power, lighting, and socket-outlet and plug installations.

The wiring of motors for large banks of machine tools with unit drives, where a layout of the machine shop is not available at the outset, makes the provision of trenches for the cables or conduits very inconvenient, and the practice of installing conduits suspended vertically from the ceiling or roof trusses has to be resorted to as an alternative to cutting chases across, in the majority of instances, a new concrete floor to each machine.

In large machine-tool shops where a layout is available, trenches with chequer plates probably provide for the best electrical distribution layout, as fuse distribution-boards, resulting in short final sub-circuits, can be erected on a steel frame at the side of, or above, the cable trenches.

Both the methods described have been used recently in installations in a factory I have been concerned with, the former method for some 25 machine tools where no layout was available at the outset, and the latter for between 50 and 60 machine tools with motors ranging from 1 h.p. to 7½ h.p. where a layout was available. In the latter case the final sub-circuits are run from six 10-way, 3-pole, sub-fuseboards fixed, as described above, on steel frames. In the former case the fuseboards were fixed on stanchions and conduits were run via roof trusses, and vertically down to the machine-tool control panels. Quite apart from the outward appearance of the two installations, the difference in the lengths of the final sub-circuits is very noticeable, the cost of the installation being reduced to a minimum, even when the cost of the trenches and chequer plating is taken into account.

PLAIN LEAD-COVERED AND ALLOY-SHEATHED CABLES

It is sometimes necessary to use, particularly in battery rooms, cables of this class, and, should there be a considerable number of these to install, a method is called for to eliminate labour in plugging and saddling the cables to the structure, and also running them in a neat and workmanlike manner.

Probably one of the best methods is to use perforated sheet steel suitably treated with an acid-resisting enamel, and to secure the cables to this by means of alloy or brass saddles.

INDUSTRIAL LIGHTING INSTALLATIONS

Artificial illumination is as old as the human race, and is essential to civilization, but in spite of this it is only in recent years that great strides have been made with the problem of efficient illumination in industrial establishments by means of electric lighting. This is, without doubt, due to the fact that this subject has now become a highly developed science, chiefly owing to the brains and money which have been expended on intensive study and experimenting by the leading manufacturers of lighting equipment and the Electric Lamp Manufacturers Association over a long period of years.

The close relationship between production and illumination in the modern factory is on every hand becoming increasingly recognized by architects, engineers, and industrialists, who now appreciate that good lighting is a profitable investment, in that it promotes production, minimizes waste of material, human effort, and the liability of accidents to employees.

These remarks are substantiated by the fact that the Home Office now call for reasonable artificial illumination in quite a number of industries.

The elimination of shadows cast by lighting units presents an interesting problem, and the contractor can take advantage of, in addition to his own experience, the wide experience and information gathered by the firms specializing in scientific illumination.

A point probably of interest to those concerned with the installation of high-wattage gasfilled lamps (i.e. 1 000 or 1 500 W), is that where two are controlled by one 15-ampere switch—which number I consider should not be exceeded even in large installations—the switch should be of the quick-make slow-break pattern, when used on a.c. supplies.

It will be found, when breaking 8·7—13 amperes on a 230-volt a.c. circuit, that there is practically no arcing with this type of switch. With a modern quick-make-and-break switch, however, one is likely, when switching off, to break such currents at or about the peak of the current wave and thus obtain a vicious arc, whereas with a slow-break switch there will be 3 or 4 cycles during which the current reaches zero during a very short travel of the moving contact as it opens, and the arc fails as the current falls to zero.

EXCEPTIONAL INSTALLATION PROBLEMS

An All-Electric Canteen Installation.

The carrying out of the main cable installation for an all-electric canteen for a large works presented a problem not altogether straightforward, as an installed capacity of 262 kW was concerned on a 200-volt 2-phase supply.

The canteen was situated on the third floor of one of the factory buildings, but the supply had to be brought from the basement of an adjoining building where the main switchgear and switch distribution-boards had already been installed. Alternative routes for the cable runs were considered, and it was decided to install the cables on the exterior of one building, running them vertically up the wall to a point where a chimney stack projecting from the face of the wall made a convenient point for securing the end of a 12 in. × 6 in. steel joist to bridge the space between the two buildings. The other end of the joist was secured to the roof of a dormer window in the other building, this gap between the two buildings being about 40 ft. above the ground-level.

Where the cables passed through the wall of the building into the basement, lead sleeves were used with bell ends and compounded to prevent ingress of water. Special cable racks made from steel channel with studs and creosoted hardwood cleats were designed, the metal work being zinc-sprayed as a protection against atmospheric conditions.

In connection with the wiring and connecting up of the large cooking gear for which armoured cables and oil switches with overload trips were used, the switches were vitreous-enamelled in order to match the ranges, ovens, and grills, etc., and this resulted in a rather exceptional occurrence.

After one of the oil switches had been connected up, a continuity test was made between the armouring of the incoming and outgoing cables, which were saddled to a wood partition. Instead of, as one would have expected, a zero test with a "megger," a reading was obtained of over 1 megohm. On investigation it was found that the armour clamping plate, and the nuts on the studs to secure the same, had been vitreous-enamelled, thus presenting a very high degree of insulation.

A test was also made for continuity on the ovens and hot cupboards, and it was again found that there was no continuity between the various vitreous-enamelled sheet steel tops and sides, although these were fixed by means of screws to a steel frame. I understand that with mass-produced cookers for domestic use special precautions are taken against such lack of continuity.

Sewage Works

A lighting and power installation in a sewage-works sludge-press house calls for careful consideration on account of the exceptional conditions encountered, as the atmosphere is extremely humid and variations in temperature result in excessive condensation. This, coupled with the presence of corrosive gases such as ammonia, necessitates special treatment of the wiring work.

A watertight conduit system under these conditions has been found unsatisfactory on account of internal condensation, and also the walls and steel work, etc., are periodically washed down by means of a high-pressure water jet from a hose.

To meet these conditions, a vulcanized-rubber metal-sheathed wiring system protected with special compound-impregnated braiding was installed. At all points where the wiring enters or leaves fuseboards, switches, socket-outlets, lighting fittings, etc., a solid alloy gland was employed, and the cable sheathing soldered to the gland, thus providing a waterproof joint.

Special alloy clips were used for running the cables, fixed by means of brass screws, into wall plugs where run on brickwork, some of the multiple runs being fixed on hardwood battens, and others on perforated sheet steel.

All fuseboards, junction boxes and switch boxes, lighting fittings, and other accessories, were of the waterproof pattern with watertight lids and were sheradized to prevent corrosion.

The cables for the 3-phase power installation were similarly protected by means of compound-impregnated braiding, this having a neater and cleaner appearance than standard serving.

POWER FACTOR CORRECTION

There is a wide field open to the contractor in connection with the installation of condensers on consumers' premises where, owing to the use of induction motors, a low power factor obtains. For large power plants the rating of the condenser may reach 200–300 kVA or more, with consequently heavy control switchgear and wiring.

It will be found that in the majority of cases where a 10 % rebate is allowed for the correction of the power-factor to 0·95, or 5 % to 0·85 or above, the cost of the condenser equipment can be saved in from 3 to 5 years, and in exceptional cases in even shorter periods.

Where the tariff is on a kVA basis the reduction in the kVA demand when a condenser is installed is in many instances quite a high figure, with obvious benefits to the consumer, as well as relieving the supply authorities' mains and distributors.

An instance has recently come to my notice where a consumer required an additional 220 h.p. of motors, and the supply authority was in a position to meet this demand without extra mains, solely owing to the fact that condensers of 165 kVA capacity were installed about 2 years ago. Without the condensers the consumer's service was practically fully loaded.

DOMESTIC INSTALLATIONS

Without doubt the utilization of electricity in thousands of houses built during even the last decade is throttled from the outset, as they are wired only for lighting and, possibly, one plug and socket-outlet for a wireless set or electric iron.

The dawn is all too slowly breaking of the era when domestic premises will be provided with adequate outlets so that at least a few of the scores of available domestic appliances can be utilized.

Unfortunately, it is inherent that existing installations cannot be easily and cheaply extended, and it would appear that, even with modern civilization and ideas, it will be necessary to go through a period of evolution similar to that when one cold-water tap in the scullery or kitchen was considered to be ample for domestic requirements.

LIGHTING FITTINGS

The designs available for pendant, ceiling, and wall-bracket fixing, are legion, and it falls to the contractor's lot to fix, wire, and connect these up in all classes of buildings.

There is still a lack of uniformity by designers regarding the fixing of lighting fittings to standard installation accessories, and the fact that there are British Standard outlet boxes with standard fixing centres does not appear to have penetrated into fittings design offices to the extent one would expect. On the other hand, certain manufacturers of lighting fittings have on their staff designers who apparently can visualize not only the economic manufacture of the lighting fitting itself, but also the fixing and wiring of it at its final destination, i.e. the lighting point. The labour entailed in fixing and connecting up is then a minimum.

Also, some of the fittings employing square, oblong, and other shaped plain or tinted glassware panes, mounted on a metal framework, are a veritable puzzle to assemble, and no instructions, suggestions, or sketches, which would save labour, accompany the fittings when received by the contractor.

THE MAINTENANCE OF ELECTRICAL EQUIPMENT

To suggest that electrical installations and equipment are free from trouble would be to beg the question, and it is the contractor's duty to be able to locate faults and failures quickly, and to know how to diagnose and remedy them.

It will generally be found that certain individuals have the happy knack, almost by instinct, coupled with experience, of noticing, particularly with rotating electrical machinery, early symptoms which precede a fault long before it becomes really obvious. Regular maintenance is one of the branches of many contractors' businesses.

It is generally acknowledged that the majority of breakdowns which occur to electrical machinery and equipment could have been prevented by proper maintenance. This does not mean that wear and tear can be prevented, but at least it can be foreseen, minimized, and remedied, before the consequent breakdown occurs.

A contractor's maintenance department should be organized to cover the regular inspection, overhauling, cleaning, and adjusting, of all types of electrical plant and apparatus, and to be capable of repairing any damage which may occur, including all renewals due to wear and tear.

WIRING REGULATIONS

The position regarding Wiring Regulations as they affect the contractor was set out in Mr. Young's presidential address a year ago, and there is little that I can add except to say that the Electricity Supply Regulations (1937) have since been published, and Regulation 25 now requires electricity supply authorities, in carrying out installation work on consumers' premises, not to accept a lower standard than that which they require of contractors. This is the first time the contractor has been protected in this way.

Regulation 25, however, does not apply to " works " (i.e. installations on consumers' premises) brought into use, or commenced, prior to 1st January, 1937, so there is some tolerance in the new Regulations with regard to old installations.

Regulation 27 of the Electricity Supply Regulations (1937) is one of the most important to the contractor. This deals with the " General Conditions as to Supply to Consumers," and contains the provision: " Provided that any consumer's installation which complies with the provisions of the I.E.E. Regulations shall be deemed to fulfil the requirements of this Regulation."

I am of the opinion that, particularly since the issue in 1927 of the 9th Edition of the I.E.E. Regulations, installation work generally is of a considerably higher standard, owing to a very great extent to these Regulations being widely used as a basis for first-class work.

It should, however, be borne in mind that the I.E.E. Regulations have as yet no statutory backing, and installations which violate them are still being connected to the supply mains. One might describe these as " permitted tolerances."

I recollect that, shortly after the publication of the 10th Edition in 1934, opinions were expressed in the electrical Press to the effect that no objection could be taken by a supply authority, contractor, or consumer, to an installation carried out in accordance with those Regulations.

In a recent case where two 15-ampere outlets were connected on a 3/·036″ (10-ampere) sub-circuit, a violation of I.E.E. Regulation 201 (E), an inspector appointed in accordance with the Electricity Supply Regulations (1937) upheld the supply authority, but on appeal to the Commissioners by the consumer the decision of the inspector was set aside and the installation connected.

The consumer's alleged contention was that there was no likelihood of more than one 2-kW radiator being in simultaneous use. Accepting these conditions for the time being, as they existed for the basis of the appeal to the Commissioners, the question immediately arises in one's mind: If cases of this nature became common, for what period would these " conditions " be likely to exist? They could be immediately altered by a new tenant, or by the existing tenant of the premises who might decide to install a 3-kW radiator.

It is to be hoped that this case will be an isolated one, as although the I.E.E. Regulations do not purport to be an inflexible guide for every possible installation requirement, they do at least endeavour to safeguard property and life under the diverse conditions for which an installation can be called upon to provide.

CONCLUSION

I have endeavoured to describe some of the activities of the contractor concerned with the heavier side of installation work, and time does not allow me to do more than mention further branches on the lighter side, such as telephones, electric clocks, wireless, floodlighting, neon signs, electric discharge lighting, refrigerators, etc., all of which present a field for the installation engineer.

It has been suggested in electrical circles that the time may arrive when all installation work on consumers' premises will be carried out by the supply authorities' contracting departments, but in my opinion that day will not be in the near future, and is unlikely to arrive unless all electricity undertakings are taken over by the State.

The genuine electrical contractor has, I feel, a definite sphere of his own in our great industry, and this section will continue to attract brains and the necessary capital in direct proportion to the openings and positions which are from time to time available.

The contractor's work, with its variety and ever-varying problems as electrical science advances, makes it as interesting as either supply or manufacturing, and if my remarks in any way convey that the contractor's sphere in the electrical industry is justified and that craftsmanship has its place in installation work, then they will not have been in vain.

SCOTTISH CENTRE: CHAIRMAN'S ADDRESS

By MAJOR HERBERT BELL, O.B.E., T.D., Member.

"A BRIEF SURVEY OF ELECTRICITY SUPPLY LEGISLATION"

(*Address delivered at* GLASGOW, *12th October*, 1937.)

In making a brief survey of the progress of electrotechnics we may all, both consciously and unconsciously, feel a justifiable pride in being associated with a branch of industry possessing the undeniable advantages of an international nomenclature and a universal set of standards; an industry, moreover, that is responsible for the production of an agency which we are justified in hoping may some day attain the ideal and be identical in its characteristics among all the constituent nations of the world.

In these days of economic nationalism and consequent international unrest, for which latter no effective remedy has so far been prescribed, it is indeed gratifying and helpful to feel that the lives of those engaged in the electrical profession are devoted mainly towards ends which in no way augment, but tend rather to diminish, national differences and materially help to bind more closely together those who for geographical, ethnological, economic, or linguistic reasons, are apparently tending to drift farther apart.

It is, for instance, probably true to say that without the inestimable boon which electricity has conferred on mankind through the gradual development of the various branches of electrical communication, commencing with submarine telegraphy and ending with wireless diffusion, society could scarcely continue and chaos must inevitably ensue.

After intense and protracted consideration of the many activities which the several Sections and Centres of The Institution envisage and discuss at their various meetings held during the working session, the conclusion has been arrived at that it is not within the power of the average human being to interest equally the whole of these. Your indulgence, therefore, is sought if, in the following remarks, a very usual procedure is adopted and an endeavour is made to engage your attention for a short time in the consideration of that branch of the electrical industry with which I am more particularly associated, viz. that of electricity supply. The wisdom of this decision is confirmed by the fact that electricity supply forms so essential and so important a link in the chain of general electrical activities that its problems, its performance, and its healthy condition, are matters which materially concern a very large proportion of the membership of The Institution, of which the Scottish Centre forms an important part.

It is now well over half a century since the first British legislation contemplating the public supply of electricity was enacted, and almost that period since the first practical attempts were made, by the pioneers of the industry, to establish undertakings for the provision of this public utility service; and the present would seem a fitting opportunity to make a brief retrospect of the progress that has been made since those early days in the legislative, technical, and commercial, aspects of its development, and, if any errors have been committed in the process of the industry's growth, to consider what remedies are desirable and possible in order to rectify such errors.

Firstly, therefore, it is not unfitting to endeavour to arrive at a sound conclusion as to whether the degree of evolution made during these 50 years is on the whole satisfactory, and in doing so a difficulty at once arises in fixing a standard by which a correct conclusion can be reached. If the relative progress achieved by other countries be used by way of comparison, then, making all due allowance for economic and physical considerations, it is probably true to say that British development has been reasonably satisfactory. Partly, however, for the purpose of deliberation it might be advantageous temporarily to assume the contrary, solely with the object of considering methods of accelerating development in the future.

At the outset, therefore, it would seem necessary to survey in perspective the legislation associated with the supply industry, and in doing so it is interesting to note that, contrary to usual precedent, the earliest of such legislation may be correctly stated to have been enacted at a date well in advance of the actual developments which it was designed to control. A cursory survey of important legislative provisions over a lengthy period seems to confirm the suggestion that this is, in many respects, almost a unique circumstance.

It may well be, therefore, that this contretemps has been in some measure responsible for certain of the difficulties at present encompassing the industry.

It will be remembered by many that almost a decade elapsed before any noticeable practical results arose from the first electrical Act, the Electric Lighting Act of 1882, and it is interesting to speculate how it was possible to draft really appropriate and advantageous legislation when the necessity for it, or the requisite experience to enable it to be successfully drafted, did not exist.

The Act is in most respects an admirable piece of legal workmanship, based as it is, to a considerable extent, upon earlier Gas Acts, but there is one of its provisions which, in the light of subsequent progress and recent developments, merits careful introspection.

During the decade immediately preceding the introduction of this Act of 1882, the local government service had been steadily developing, and this new electrical industry naturally offered an attractive outlet for experiment with the principles of public ownership and control. Having regard to the limited ambit and possibilities of electrical schemes at that time, it can easily be demonstrated that the bill drafters of those days were justified in their attitude on this point. Not content, however, to rely solely upon this latter method of procedure, the legislature sought further to ensure a more intense expansion of the new industry by additionally contemplating the alternative possibility of evolution by means of private ownership, with the result that the selection of the method of development in any area was haphazard and governed to a large extent by the relative initiative of the local authority and any interested private enterprise.

In spite of this anomaly, general development by public authorities was on the whole satisfactory, and after the introduction of a further Act in 1888 whereby the security of tenure of company undertakers was prolonged and enhanced, procedure by means of private enterprise showed a tendency to expand and increase.

With the exception of the Metropolis and one or two provincial cities, competitive supplies were not permitted, the exceptions in all cases being naturally restricted to private undertakings.

During the ensuing decade, commencing about 1900, the technique of electricity supply had made such strides that a new school of thought had arisen, the exponents of which held that supply for power purposes would ultimately, from every point of view, assume very much more extensive proportions than, and would completely predominate over, that for lighting. They further held that the boundaries of most of the local authority undertakers were too parochial and too arbitrary ever to permit of any reasonably rapid progress being made under existing legislation. The result was that during that period a number of private Power Acts were passed which had the effect of entirely re-orienting the whole outlook of electricity supply, restricting as they did, solely to private enterprise, the exclusive rights of production in relatively large areas uncorrelated with each other or with any existent areas of supply, many of which latter were completely enveloped as a result of this legislation.

The intrusion of these Acts introduced the element of competition and duality of supply in certain circumstances which, with the exceptions already mentioned, had fortunately been non-existent.

Viewed in the light of the situation at the opening of the century, some of these private Power Acts were desirable and in a number of cases were the means of achieving results which were both meritorious and of national advantage, but, unfortunately, any schemes developed thereby, through the lack of co-ordination with existing areas of supply just referred to, suffered in just the same way as the latter from a complete lack of perspective as regards the eventual creation of an electrified Britain.

Towards the end of the decade in question, arising from the greatly increased requirements of the public, there was sporadic but persistent evidence that all was not well with the industry. Its ability to supply was still definitely limited in point of district, and it was becoming increasingly obvious that development under the combination of the original legislation and the subsequent Power Acts was not achieving that degree of progress which had been expected. This is made abundantly clear by a brief survey of the next attempt at electric legislation, viz. the Electric Lighting Act of 1909, which, although timid in conception and limited in ambit, definitely endeavoured to sow the first seeds of expansion and co-ordination and to effect the development of areas at that time lying electrically dormant.

It is interesting here to note the lack of perspective in the title of this Act, viz. " The Electric Lighting Act, 1909," inasmuch as its provisions were jointly applicable to all classes of undertaker and to all classes of service; and, as might have been anticipated from its very title and the tentative nature of its provisions, although incorporating a number of unmistakably useful measures, it can be definitely stated that it achieved comparatively little towards the development of the supply industry on a broad and comprehensive basis.

Entering upon the decade of the Great War, Britain, and the Continent of Europe generally, suddenly became electrically conscious owing, to a very large extent, to the enormous demands resulting from the abnormal conditions which had then arisen, and as a result almost a spate of committees, official and unofficial, were from time to time set up. The Electricity (Supply) Acts of 1919 and 1922 were the result of some of these deliberations.

The former, although containing a number of desirable features, such as a wise provision for the setting up of a national statutory authority for the better control of the industry, was so emasculated in its passage through Parliament as to be of little value as far as general rationalization was concerned. Similar remarks apply to its descendant Act, that of 1922, which, curiously enough, to a certain extent acted as a detergent to some of the progressive provisions of its progenitor.

Probably one of the root causes of the general lack of legislative progress around this period may be traced to the fact that the issues involved in connection with electricity supply were becoming of such national importance that the whole problem began to assume a political character, each successive political party having its own particular nostrums for achieving an early remedy for the immediate difficulties.

By the middle of the period in question, however, there was a further re-orientation of thought and an apparent realization that, if early genuine improvement and development of the industry was to be achieved, this, paradoxically enough, could only be effected by dealing with the matter in a gradatory manner, and the Electricity (Supply) Act of 1926 was the direct result. This Act, although it contained one or two clauses bearing upon the question of reorganization of distribution, was confined in the main to provisions devoted almost exclusively to the co-ordination of generation and its very natural corollary, standardization, insofar only as generation was affected by the latter.

Ten years' experience of the operation of this Act, and a further universal and definite readjustment of ideas with regard to the relative importance and relative difficulties as between production and distribution of commodities in general, appear to have made it only too clear that all those electrical ideals so trenchantly elaborated in 1925 and 1926 are not materially nearer to fruition to-day than at the time they were advanced, and the appointment of a Departmental Committee in the summer of 1935, charged with the duty of again investigating the situation, appears to confirm the accuracy of this assumption.

The Report of this Committee's deliberations has now been public property for some little time, and it is understood to be the forerunner of a new Distribution Bill. It would be neither politic nor profitable to endeavour in any way to forecast the character or contents of this Bill, but, as sufficient evidence is now available to confirm that it is to be based upon the findings of the Report, it would appear wise that members of the Scottish Centre should have a concerted idea both of the terms of reference to, and the conclusions and recommendations of, the Committee, so that they may individually exercise a discerning discretion in their interpretation of the Bill and in their advocacy or criticism of its various provisions.

A careful analysis of the terms of reference to the Committee indicates:—

A general instruction to review the organization of distribution.

A series of specific instructions to recommend methods by which expedition can be achieved:—

(i) In standardization of system and voltage; and standardization of methods of charge.

(ii) In early expansion of supply facilities.

(iii) In reduction of costs.

It would seem that the essentially fundamental portions of the reference are those relating to "Expansion" and "Costs," and a broad and reasonably concise interpretation of their purport would appear to be:—

How can electricity be made more generally available? and—

How can its selling price be brought to the lowest possible figure?

The remainder of the terms relate in reality to features ancillary to one or both of the above prescriptions.

A survey of the contents of the Committee's Report and Recommendations reveals that in their opinion amelioration can be achieved almost wholly through the medium of a reduced number of undertakings.

After a careful review of this recommendation, in general it will be conceded that, starting *ab initio*, the smaller the number of areas of supply the easier will be their development; but as the 635 undertakings referred to in the Report are established *de facto*, it seems difficult to conceive how their number can be materially reduced without the introduction of countervailing disadvantages of one kind or another.

It is also difficult to contemplate the effective amalgamation of a number of undertakers into one coordinated whole unless the constituents thereof are providing and selling what may be conveniently termed the same type of article. As the Report indicates when dealing with standardization of system and voltage, such is by no means the case; but the Report is, unfortunately, almost silent as to any concrete remedial proposals, leaving these, generally speaking, as matters to be rectified principally in the course of time.

It is not, of course, here suggested in respect of standardization that the condition of affairs in the electricity supply industry in Great Britain is at present more chaotic than is the case on the European Continent, in fact a recent survey which I have made indicates that the reverse may be the case; but, nevertheless, it is urged that a bold and immediate envisagement of the problem which has to be met would undoubtedly achieve the more quickly that reorganization which both the Report advocates and the industry as a whole so devoutly desires.

The consequences of delayed action can perhaps be better appreciated if we contemplate how entirely impossible the position of rail transport in Great Britain would be had not standardization of railway gauges been effected some 50 years ago. Additionally, many millions of pounds sterling would have been saved had the various Continental States adopted one standard gauge before railway development reached the stage at which standardization became financially impossible.

It is postulated, therefore, that amalgamation, without contemporaneous standardization, firstly of system, and, as a corollary thereto, of voltage, would very largely rob the proposed reorganization of its principal virtues, viz. increased simplicity for distributor and user, and reduction of costs to both, arising from manufacturing rationalization.

Standardization of Methods of Charge.

It will be at once conceded by all those engaged in the industry that the present multifarious methods of charge are unjustifiable, but, unfortunately, having admitted this, it becomes almost impossible to advance even an approximate remedy; and when it is further realized that from the consumer's point of view it is not so much the method of charge but rather the actual charge which is the acid test that he applies, the difficulty becomes still greater.

It has been frequently contended by critics that there should be uniformity of electricity charges in all districts, in much the same way as applies with certain of the older and simpler services of the Post Office, but closer study will reveal that this ideal applies by no means universally throughout the whole of the latter's activities.

Before, therefore, any extensive improvement can be effected in the direction of rationalization of existent methods of charge, and arising therefrom of possible attempts at standardization of actual charges, certain definite principles must first be evolved as to the correct basis of these charges, the elaboration of which, contrary to the suggestion in the Report, should not, it is contended, be left to regional effort.

It would be profitable at this juncture to make a slight digression in order to review generally the various aspects of electricity tariffs from the early days of the industry.

Exactly 45 years ago Dr. John Hopkinson delivered the first scientific pronouncement relative to his conception of the ideal basic principles of electricity tariffs.

Very briefly interpreted, these were that it was comparatively easy to ascertain the cost of supply to individual consumers and that, in fact, each consumer should be charged upon the basis of such cost, with the addition of a reasonable margin of profit.

The principle is particularly attractive and one to which the whole commercial world has given lip service from the earliest beginnings of industry. It is interesting, therefore, to study the history of electricity tariffs from the time of the above pronouncement.

At the time this was made, most of the electrical energy produced was sold for a single purpose, viz. for lighting. Other uses were developed from time to time, and had the principles of Hopkinson and his disciples been capable of universal practical application, no difficulties would have arisen and each class of user would have been automatically charged, by the same method, an amount equivalent to the cost of his supply, plus profit.

What actually happened was that as each new use for electricity developed, a collateral new tariff was formulated which was, generally speaking, uncorrelated with the already-established lighting tariffs, and a consideration of the printed scale of charges of undertakers in general to-day will show that the number of these new tariffs has steadily increased with the extended usages to which electricity has been applied.

One is justified in asking a reason for the necessity for these new tariffs, and the obvious answer is that they were instituted for the better development of new phases of the industry; and with the object of accelerating those developments they had, as is usual in commerce, to be preferential in character, or, expressed in a different way, the principle of selling on the basis of cost had in their case to be largely abandoned and a principle, new but nevertheless necessary, introduced in its place, viz. that of selling on value.

This new theory was ably and exhaustively expounded by Mr. Edward Cowan in a paper which he read before the British Association as far back as 1910, and a fair interpretation of the discussion which the paper evoked and which was contributed to by responsible members of the supply industry, is that Cowan's deductions were generally sound and that universal application of the principle of selling on cost was neither practicable nor desirable.

The object of this slight digression is to endeavour to show the magnitude of the difficulties which will arise in the process of standardization of methods of charge unless certain broad principles arising upon these aspects of the case are definitely settled before such standardization is attempted.

To make this point perfectly clear, one may quite logically ask, in view of the recommendations of the Report, how the number and character of the various methods of charge will be determined in each area and upon which of the above two principles these methods will be evolved.

If the answer is that the principles of Hopkinson are as universally applicable to-day as they were when formulated, then grave difficulties will arise in the justification of certain existent tariffs, which the most ardent advocate would find extreme difficulty in supporting on any grounds other than those of expediency.

An excellent example of such a difficulty would be the case of tariffs for storage water-heating which involve the introduction of a secret and variable component in the shape of a set of restrictive conditions, which frequently differ in each particular case.

It is believed that the recommendation in the Report relative to flexibility in "Special" classes of supply is intended to meet all cases where the Hopkinson principle has, on the grounds of expediency, to be departed from; but the difficulty immediately arises of correctly deciding which types of supply fall in the category of "Special," and, in view of the fact that there are so many such types, attempts at standardization of method must of necessity be considerably stultified thereby.

It is suggested, therefore, that, whether the number of existent areas be reduced or not, before any great hope can be entertained of removing the stigma said to be attached to electricity tariffs in general it is essential that the broad principles just referred to be definitely settled.

Early Expansion of Supply Facilities.

Intrinsically, as has been previously pointed out, this recommendation, together with that following and relating to reduction of costs, is the indispensable essence of any attempt at reorganization, and the extreme difficulties which have beset the Committee in finding even an approximate panacea, are evident in the paucity of their proposals.

The principal among the concrete proposals are:—

(1) *Assisted Wiring.*

In this connection it may be said that, during the last quinquennium, the principles of hire-purchase have made such remarkable strides that there is practically no trade which does not cater for sales on such terms, and it has been the experience of those undertakers who have engaged over a long period in hire-purchase activities that these have been materially curtailed by the widespread adoption of deferred-payment facilities in the retail trade generally.

(2) *Contemporaneous Development of Rural Areas.*

In regard to this recommendation, in the absence of any essentially new proposals, development in what at present constitute unremunerative areas can only be effected at the expense, and to the detriment, of the contiguous successful areas, whether publicly or privately owned, and difficulties must inevitably arise from the adoption of a policy of this character.

(3) *Reduction of Costs.*

The opinion is expressed that, with the exception of the hypothesis that amalgamation will automatically bring about reduction in costs, there are virtually no momentous proposals in this section.

(4) *Miscellaneous Recommendations.*

The remaining recommendations are varied in character and, with one exception—that relating to consolidation of legislation—call for no special consideration in this Address. In the early portion of these remarks an endeavour has been made to show how fragmentary and often antithetical are the various legal enactments relating to electricity supply, and there is little doubt that there will be consensus of opinion endorsing the desirability of this recommendation; but there is a particular aspect of the matter which deserves careful consideration. The wording of the recommendation gives no indication whether such consolidation would be achieved contemporaneously with, or subsequently to, any enactment which may be put into force as a result of other recommendations in the Report. To defer consolidation would, it is suggested, be an evasion of our proper duties and responsibilities and would result eventually in a situation almost comparable with that of Scylla and Charybdis.

For these reasons, therefore, difficult as the problem of consolidation of existing legal enactments will be, delay will cause even greater difficulties, and it is here urged that it is infinitely wiser to encounter these with immediate confidence.

Since the passing of the Act of 1926, there have been two further Acts, viz. those of 1935 and 1936. The former is a short Act which, it will be remembered, is ancillary to the principal Act of 1926; while the latter deals exclusively with the essentially domestic matter of meters, and can scarcely claim to play a very important part in materially furthering the general availability of electricity or in a reduction in the cost thereof.

Reflection on the whole of the points covered in this brief review will inevitably lead to the conclusion that if volume of legislation is the primary consideration the supply industry has been most generously treated—so generously, in fact, as to prompt the thought that it would be desirable not to add thereto unless and until any such additions have been so formulated, so matured, and so generally digested, that it can with certainty be affirmed that they will considerably reduce those errors and difficulties which have arisen in the past, and will largely achieve the ends envisaged in the Government's terms of reference.

It requires but little contemplation to realize that the present juncture will inevitably constitute an epoch in electricity supply, necessitating the most careful deliberation before a remedy can be prepared which will effectually coalesce and harmonize those antithetical principles of previous legislation, and produce with the minimum disturbance the ends which all very rightly desire.

MERSEY AND NORTH WALES (LIVERPOOL) CENTRE: CHAIRMAN'S ADDRESS

By G. K. PATON, Member.

"THE PROBLEM OF RURAL ELECTRIFICATION"

(ABSTRACT *of Address delivered at* LIVERPOOL, 18*th October*, 1937.)

My address refers to a problem which is of particular interest to North Wales and to other parts of the country at the present time. I propose to discuss some of the difficulties which are met with in the development of rural areas, North Wales in particular; but similar conditions exist in other areas, and if these difficulties can be overcome it may assist in the provision of supplies of electricity in areas which so far are sterile as regards electrical development.

The expression "Rural Development" covers a very wide field, and in the North Wales and South Cheshire Electricity District we have perhaps a greater diversity of rural conditions than is usually met with in one undertaking. Whereas Cheshire is a rich farming county with large dairy farms, capable of taking and paying for a supply of electricity which can be used extensively, in North Wales we have Anglesey and other Welsh counties of low rateable value, with widely scattered small farms and large tracts of mountain land where electricity is not in such great demand. Under such conditions it is the commercial aspect which requires most careful consideration in planning a rural development. As a rule the technical and purely engineering part of the scheme is quite straightforward.

Supply undertakings have been criticized on the ground that only the remunerative parts of their areas have been developed, the thinner parts of the area being left undeveloped until pressure is brought to bear upon the undertakers by the local councils. This criticism is not quite justified, as the proper sequence of expansion must be to develop the areas which will provide sufficient revenue to justify the initial part of a development scheme, which as a rule is the major part. It is only when the initial scheme becomes revenue-earning that the further development can be justified on an averaging basis. Perhaps when we have a national scheme this method may be revised.

The Report of the Committee on Electricity Distribution (the McGowan Report), dated the 8th May, 1936, addressed to the Minister of Transport, is quoted, particularly the section dealing with rural areas in paragraphs 376, 385, 387, 391, and 476.

Considerable development has already taken place throughout the North Wales and South Cheshire area, over 40 000 consumers having been connected to the mains in the last few years, and progress is still maintained at the rate of over 6 000 consumers per annum.

This expansion has taken place in a mixed area which includes the smaller urban areas and townships which are the centres of extensive rural districts, but does not include developments in the areas of the local-authority undertakings, which take supply in bulk.

The areas yet to be developed are sparsely populated and at considerable distance from existing transmission lines. Consequently, development is becoming more costly and less remunerative to the undertakers, and there is difficulty in obtaining sufficient demand to justify such developments on a commercial basis.

The problem is to develop these very thin areas in which there is a limited demand for supply, and at the same time offer throughout the area an attractive tariff which is not greatly in excess of the tariff rates now available in the urban areas within the district.

One might study with interest the results of the Bedford Rural Scheme which is analysed in the 16th Annual Report of the Electricity Commissioners. This scheme covers an area of only 109 square miles, with a population of 21 638, surely an ideal area for a demonstration scheme, particularly when energy is purchased at a very low price, lower than the grid tariff, at an average rate of 0·3858d. per kWh.

The financial result is a loss of £6 520 in 1936, and the accumulated deficiency amounts to £22 314. It is interesting to note that the flat-rate tariff is 8d. per kWh, but the average price obtained is only 0·835d. per kWh, and it is evident that the latter is too low.

The Norwich scheme is perhaps more rural, but the conditions appear to be ideal for a demonstration scheme, as the area is only 125 square miles, with a population of 13 744, an average of 110 per square mile.

In this scheme the average capital cost of mains is £650 per mile, which compares with £1 100 per mile in Bedford. The difference is probably due to the greater use of underground cables in the latter scheme.

The average purchased energy cost is only 0·354d. per kWh on a tariff of £2·93 per kW + 0·122d. per kWh, an exceptionally low price. The financial result is a loss of £2 800 in 1936, with an accumulated deficiency of £13 809.

The results of these two demonstration schemes are quoted, as the conditions as regards size of area and cost of energy are ideal from a supply point of view, and in each case the undertaking has been financially subsidized by the Treasury.

In contrast the report also gives the results obtained in Dumfriesshire, where the County Council of Dumfries has carried out a complete scheme throughout an area of 1 071 square miles.

The population of the area is 58 252, or an average of only 54 per square mile. There are 6 290 consumers connected to 628 miles of transmission line, or only an average of 10 per mile of line. The capital cost per consumer connected is £58, and the cost of energy is 0·563d. per kWh. In this scheme the financial result shows a gross surplus of £18 601, which is approximately 5 % on the capital cost. This scheme reflects great credit on those responsible for its development.

In Anglesey we have a county of 276 square miles with an average population of 178, but if Holyhead and Menai Bridge are omitted, both being served by the local-authority undertakings, there remains an area of 273 square miles with an average population of 135 per square mile. This compares with:—

	Average population per square mile	Capital cost per consumer connected
Bedford area	198	£54
Norwich area	110	£46
Dumfriesshire area, not including Dumfries	54	£58
Certain distribution areas in England	216	£40
North Wales area	192	£23

The County of Anglesey forms part of the North Wales and South Cheshire Electricity District, and a considerable amount of capital has already been spent in carrying out schemes under Development Orders Nos. 1 and 2. The scheme is not complete and further areas have yet to be developed, but the estimated capital cost in these initial schemes does not exceed £36 per consumer connected.

From the figures I have quoted it would appear that the capital cost of the undertaking per consumer connected in rural areas other than North Wales is from 60 % to 100 % greater than the corresponding cost in an urban area of supply. The average revenue per consumer in the rural areas appears to be from £5 to £6, and it is also noted that the ratio of connected load to maximum demand is also about the same in all the rural areas, viz. 5·9 : 1·0.

With the actual trading results of these demonstration schemes in mind where the areas are small, fully developed, and enjoying the advantage of exceptionally low cost of energy delivered and without any further cost of transmission, let us consider what happens in a large area, such as North Wales, where supply is given over an extensive mixed area of over 4 000 square miles. What are the present conditions in that area?

The Electricity District was formed under the North Wales and South Cheshire Electricity Order (1923) constituting the North Wales and South Cheshire Joint Electricity Authority, and the executive powers of the Authority were transferred to the North Wales Power Co., Ltd., operating throughout the whole area of 4 000 square miles. The Power Co. under the original North Wales Electric Power Act of 1904 are authorized to supply power in bulk to authorized distributors and also to power consumers, and with the transferred powers of the Joint Electricity Authority are now enabled to distribute in all parts of the area not covered by Special Orders. These additional powers of distribution were confirmed to the Power Co. under the North Wales Electric Power Act of 1934.

The intentions of the Electricity Supply Act of 1919 were to provide a more abundant and cheaper supply of electricity throughout the country, and this was achieved in North Wales by the construction of an extensive system of overhead lines, giving a supply in bulk to practically all the local-authority undertakers in the area and also power supplies to large industrial users. Under such a scheme with an extensive transmission system, the cost of energy must of necessity be averaged and each consumer must bear his proportionate cost. The Power Co. have developed the natural hydro-electric power resources of North Wales for distribution throughout their area, and this was supplemented in 1934 by a supply from the Central Electricity Board system near Crewe.

Supply in bulk is given to 17 local-authority undertakers who distribute within their own area of supply.

One of the principal functions of the Joint Electricity Authority is to provide a supply of electricity in areas where no supply is available and where there is a reasonable demand to justify the cost of giving such supply.

With the consent of the Joint Electricity Authority a distribution company was formed to carry out this important service, and Electricity Distribution of North Wales and District, Ltd., a subsidiary of the Power Co. and now operated by them, holds 18 Special Orders which cover a very large proportion of the rural areas within the North Wales and South Cheshire District. These areas are entirely rural in character, comprising rich, fertile areas such as South Cheshire and part of Shropshire, and, on the other hand, large areas in Denbighshire, Flintshire, Montgomeryshire, Caernarvonshire, Anglesey, and Merionethshire.

The Distribution Co. purchase their supplies in bulk at over 200 points of supply from the Power Co.'s main transmission system, and have also built up their own secondary system to meet the increasing demands throughout the areas in which they supply.

The Distribution Co. are therefore operating in a manner similar to other authorized undertakers who purchase in bulk, except that they distribute over much larger and less densely populated areas. The Power Co. also distribute under the transferred powers of the Joint Electricity Authority, and the County of Anglesey, which formed part of the area of supply under the Company's 1904 Act, is one of the larger areas to be developed under a Distribution Order from the Electricity Commissioners.

I have already indicated that the average capital cost of development for distribution purposes in this area is about £23 per consumer connected, as compared with £40 to £60 in certain other developments. Examination of the transmission layout in North Wales will show that the development in these areas has been carried out as a natural sequence to the construction of the main transmission system of the Power Co. through these particular areas, and consequently the extension of the secondary high-tension mains is much less than would be normally required to supply these areas. In other words, the rural distribution network has in most cases been built up as an extension from the main transmission system in the initial stages and we are now faced with more extensive transmission to develop the remaining areas which are more remote from the source of supply. The cost of these developments is likely to be of the order of £50 per consumer connected.

While it is perhaps true to say that the initial rural development costs in North Wales are lower than elsewhere, it follows that the cost of supply must include a proper proportion of the transmission costs of the Power Co. in giving supply from their system. In an area such as this, with over 1 000 miles of main transmission route, the transmission charges are an important factor in arriving at the true cost of supply in any particular rural area, and the demand in those areas so developed forms a by no means unimportant part in helping to reduce charges to all consumers taking supply from the system.

These costs have been calculated in order to show the application of Section 12 of the Electricity Act of 1926 in so far as it affects an indirect supply from the C.E.B. to authorized undertakers taking supply in bulk under post-1926 agreements with the Power Co.

It was found to be quite impracticable to apply Section 12 charges, and in the North Wales Power Act of 1934 Clause 8 was agreed whereby at the discretion of the Electricity Commissioners the transmission charges could be computed as an average, this being followed by the Electricity Act of 1935 in which Clause 3 provides for the amendment of Section 12 of the 1926 Act in a similar manner.

It is important to consider the effect of the 1926 Act in this area. Whereas under the Electricity Act of 1919 a supply in bulk could be negotiated by agreement with the authorized undertakers, the 1926 Act definitely states under Section 12 (now amended by the 1935 Act) how the charges for an indirect supply in bulk shall be computed, and it provides that authorized undertakers taking an indirect supply in bulk from the C.E.B. shall only pay the proper proportion of the charges on the transmission lines used by them in taking such supply. Unless, therefore, the costs of all transmission lines used for supply in rural areas are pooled with the transmission lines which supply the other undertakers in the area, the local-authority undertakers do *not* contribute in any way towards the cost of supply to the rural areas. The intention of the clause was no doubt to protect the bulk-supply consumer and the Power Co., but the effect has been to create greater difficulty with consumers.

On the other hand, the demands set up by all consumers who derive their supply from what might be called the main transmission busbars connecting the generating stations and the C.E.B. point of supply at Crewe, do assist materially in sharing the main transmission charges and also in reducing these charges by their demands and the increased diversity of the system, which is of the order of 1·7. There is little diversity in the demands of the 17 local-authority undertakers, not more than a ratio of 1·05; these are of course recorded during the four winter months in accordance with the grid tariff.

I return now to the conclusions and recommendations in the Report on Electricity Distribution, so far as they affect the supplies in rural areas. It is clear that rural development, particularly that which remains to be done in this area, cannot be carried out independently on an economic basis without some form of subsidy if consumers are to obtain supplies of electricity at prices which will enable full use to be made of the service. The developments must be carried out in conjunction with other areas of greater density, such as urban areas, boroughs, or, as we have done in North Wales, in conjunction with a system which caters for industrial development, power users, and supplies in bulk.

The recommendation that rural areas should as far as practicable be grouped with urban areas is perhaps not so important in this area as in others, on account of the location of the larger urban areas, and, with the exception of local-authority undertakings, the benefits already exist.

The proposed elimination of duplicate powers and the amalgamation of all undertakings into one economic unit is a step in the right direction, as it would remove once and for always the difficult boundary question with the necessity for Fringe Orders, and would at the same time enable the question of tariffs to be dealt with on an economic and more uniform basis.

It must be obvious that under such a proposal with one large undertaking, full advantage can be taken of the greater diversity of the system and also the advantage of lower increment rates under the grid tariff if power is purchased in bulk under grid terms.

Another recommendation is that the Minister of Transport should be empowered when granting compulsory wayleaves to fix the wayleave rentals and compensation. My experience is that landowners, their agents, and tenants, have generally given every assistance and willingly agreed to grant the facilities required. The difficulty is, however, that one owner or tenant may cause delay and expense in the construction of a line and so prevent supply being given within a reasonable time to consumers. The present position is most unsatisfactory and is being exploited by obstructive methods.

Time is lost in an endeavour to overcome the difficulties, and it is only as a last resort that the matter is referred to the Minister of Transport under Section 22 of the 1919 Act. This takes time and, if a Compulsory Order is granted, terms have still to be agreed or, failing agreement, settled by arbitration, and the cost might very well be prohibitive should the question of amenities be considered.

Delays of 12 to 18 months have occurred in the completion of a development, caused by one dissentient owner. The undertaker is in some difficulty, as the actual cash value of the wayleave may only be a few pounds, but with such a principle at stake, and in order to keep faith with those who willingly grant facilities, it would be unwise and unfair to give way, although it is perhaps the easier way. I readily endorse the recommendation of the Committee and would add that the sooner it is put into effect the better it will be for those concerned in rural electrification.

Reference is made in the Report on Electricity Distribution to the variation in treatment accorded to electricity undertakings by the numerous assessment authorities in a large area of supply. The remedy suggested in the report is that the undertakings should be assessed as a whole, the cumulo value being subsequently apportioned among the parishes in which the undertaking operates, but so that the aggregate amount assessed would not exceed the cumulo value of the undertaking as an entity.

This method has already been adopted in the greater part of North Wales. Rural authorities enjoy an improvement of their areas immediately electricity is made available, and the total amount paid in rates by an undertaking is from 6 % to 10 % of its gross revenue, a very considerable sum in a large area such as North Wales.

To enable this amount to be properly apportioned, the undertaker is required to keep records of consumers and revenue in parishes (over 200 in the North Wales and South Cheshire area), and the record of mains and capital value in parishes, which, together with cost of labour and time taken in negotiations and adjustments, all add to the cost to the consumer by this unproductive labour.

The development of a rural area may show such a low return on the capital expenditure involved that the rates payable on the high-tension line transmitting the supply, plus the cost of rates payable on the actual supply itself, may reduce the estimated surplus to an exceeding y small amount, in some cases a loss, particularly in the earlier years.

Rates are payable immediately the lines are made available for supply, and the fact that a loss would be incurred for some years may prevent such areas being developed, particularly as these losses would be borne by the consumers in other areas and might even result in the prevention of a reduction of price to the consumers.

In a large undertaking extending into several counties another aspect of the incidence of rates is that the undertaking is often called upon to pay more than its fair share of the expenses of the rating authority, compared with owners of other property.

The assessments upon the undertaking usually follow one basis of assessment throughout the whole area of supply, but there is not always uniformity of valuation for other properties in the area. The result is that in many of the rural areas where the local authority prefers a low rateable value on general properties rather than values more consistent with their letting value, but imposes a high-rate poundage in order to obtain the required revenue, the undertaking contributes a much larger proportion of the revenue obtained from the rates levied. The time may come when the whole basis of local-government taxation will be completely overhauled, and perhaps then some measure of equity will be given to undertakers who desire to extend as much as possible into the rural areas. Meanwhile it is suggested that, as rural areas benefit from the electrical development of their areas, some greater measure of encouragement might be given in a practical way, and if it is not possible to obtain relief of rates for the first five years it should be possible to arrange that new rural schemes of supply made available during a quinquennial period might remain unassessed until the next general re-valuation.

Co-operation with county and rural authorities on these lines would perhaps lead to greater development of the more rural districts and give undertakers more incentive to extend to these areas. As it is, self-supporting areas present no difficulty and it is the more remote rural areas which do require some measure of assistance, some of which is under the immediate control of the county authorities.

Another matter which at the moment is seriously interfering with the construction side of rural development is the operation of the Restriction of Ribbon Development Act, 1935.

This Act, while framed for quite another purpose, has unwittingly caused considerable delay in completion of rural developments owing to the difficulty of reaching agreement in the fixing of pole positions on low-tension developments.

Agreement *can* be reached and has been provisionally reached in order to lessen the delay in special cases, but this question of road-widening, and the conditions sometimes attached to the consent of a county council when given, have definitely added to the difficulties of giving supplies within a reasonable time. The co-operation and assistance of rural and county councils might with advantage be accorded the supply undertaking in these circumstances to avoid undue cost and delay.

The question of service to consumers in rural areas is one of increasing importance. I do not subscribe to the idea that rural electrification means the construction of cheap overhead lines with cheap fuses to protect transformers, and that a cheap supply can only be given by the cheapest form of construction.

Costs must be kept to a reasonable limit, but I still consider that service must dictate in the methods to be adopted, particularly now that the rural industries—dairy farming, milk factories, and others—require continuity of supply equally with other consumers. The dairy farmer with his modern milking equipment must have his electricity supply available when required without interruption. Milk factories must keep to a definite timetable to ensure deliveries by train to their customers. Service to meet these conditions means a standard of construction which is comparable with that employed for main transmission lines, the provision of modern type of reclosing switchgear equipment to restore supply without loss of time after minor interruptions, and possibly the completion of ring mains. It must be remembered that in many cases dairy farming is the justification of a rural development, and the farmer's commitments must be taken into account if success is to be achieved and satisfaction given.

From my experience I find that most interruptions are caused by lightning, the operation of outdoor h.t. fuses, and storm damage by flying debris, such as grass and bracken, and that the faults are mostly failures to earth on one phase. The Electricity Regulations provide for a system being earthed at the neutral point, and this condition has definitely caused undue delays in the restoration of supplies under existing conditions. Continuity of supply is essential, and in countries other than Great Britain considerable use is made of the unearthed system and also the device known as the Petersen or arc-suppression coil. This system is now being tested out in service by certain company undertakers and I fully anticipate that it will be used to a greater extent once it has been proved satisfactory in service in this country. With this system, coupled with the greater use of reclosing devices on feeder switchgear, I look forward to a considerable improvement in the operation of supply systems generally.

I should like to mention one feature of rural supplies which could with advantage be improved. I refer to street lighting. The present system in villages and small townships is a relic of the past, and is subject to the parish council adopting the Lighting and Watching Act, which limits the expenditure on street lighting to very low limits.

The amount of street lighting provided is governed by the sums available, and this often results in the provision of a few lamps some hundreds of yards apart, little consideration being given to the efficiency or quality of the lighting.

The system is completely out of date and the remedy is for the public lighting of streets to be controlled by the Minister of Transport and a definite standard or standards of lighting specified on a proper scientific basis, to be carried out by county councils or whichever authority is authorized by the Minister of Transport to carry out the lighting of the roads.

I further suggest that the Minister of Transport, as the Minister responsible for the construction and maintenance of main roads, might also assume the responsibility of providing, in the road estimates of all main roads passing through rural villages, a sum sufficient to cover the cost of the feeder cables necessary to ensure efficient lighting at all crossroads and in villages, in order to secure greater freedom from accident and danger to the public generally. I am certain the undertaking for the area would gladly co-operate in such measures of safety.

In conclusion, I would summarize the present position as regards rural electrification in this country. The McGowan Report in paragraph 385 divides the rural areas in which supplies of electricity are not yet available into two main categories:

(1) Those areas in which it may be anticipated that a supply can be provided under a comprehensive scheme and which, perhaps not immediately remunerative, would show an economic return in the course of a few years.

(2) Those areas in which, owing to their geographical situation combined with an extremely low density of population, it is unlikely that a supply can be given economically, except perhaps with some form of subsidy.

The recommendation of the Committee is that in the proposed schemes rural areas should as far as possible be grouped with urban areas; they do not recommend any form of government subsidy.

It would appear that the recommendation refers more particularly to the areas in the first category and to areas immediately adjacent to large urban areas. The problem of the more remote areas such as we have in Wales is still with us and can only be solved by the gradual extension of the transmission system through those areas where the demand for electricity can be justified on some average basis.

The co-operation and assistance of the authorities is also necessary to overcome the difficulties met with in the past and reduce the heavy on-costs now incurred in planning and carrying out such developments.

The extent to which further development can be made in rural areas will depend on the margin of profit which can be earned in the more densely populated part of the area to recoup the losses in the early years of development in the rural areas.

The problem is still an economic one and is at present made more difficult by the low level of prices in the urban areas for public supply of electricity.

NORTH-WESTERN CENTRE: CHAIRMAN'S ADDRESS

By J. W. THOMAS, B.Sc.Tech., LL.B., Member.

"THE ENGINEER: HIS PROFESSION AND HIS PLACE IN THE COMMUNITY"

(*Address delivered at* MANCHESTER, *19th October*, 1937.)

INTRODUCTION

The opening of a new session affords a convenient opportunity of reflecting upon the general aims of The Institution and the present position of electrical engineers both as professional men and as active participants in the industrial and economic life of the country. During the next few months we shall be occupied in listening to and discussing technical papers dealing with the wide range which electrical engineering now covers, but before we commence we can properly ask ourselves what is the objective which we have in view and why engineers associate themselves together to attain it.

If we are to answer this question we shall have to know something more about the engineer and his profession. I propose, therefore, to deal in this Address with the engineer, his profession and his place in the community.

It is, perhaps, hardly necessary to remind ourselves of what is meant when we speak of an engineer. He has been often and variously defined, but perhaps the simplest definition is that he is a person who harnesses and utilizes the forces and materials of nature in the service of man. The definition contained in the charter of The Institution of Civil Engineers is well known. It states that certain persons had formed themselves into a society " for promoting the acquisition of that species of knowledge which constitutes the profession of civil engineering, being the art of directing the great sources of power in nature for the use and convenience of man." He must, therefore, be not only a discoverer but also in a sense a craftsman. He combines some of the functions of the scientist with the skill of the mechanician. It is his task to discover the workings of nature and to apply that knowledge to the satisfaction of human desires and the increase of the amenities of life. In a sense he has one foot in the academic world and the other in the world of affairs. He must know not only what is theoretically possible but also what is commercially and economically practicable. He must have close contact with inanimate materials and also with human beings and be capable of co-operation with them. In short, he must possess a definite technique which, in many respects, distinguishes him from the members of other professions.

WHAT IS A PROFESSION?

It may be asked at this stage whether the engineer can rightly claim to call himself a professional man. The mere fact that engineers, singly and collectively, have been largely responsible for the progress of inventions and mechanization and for the consequent increased powers of production and improved means of transport and communication, does not necessarily mean that they are members of a profession. To constitute a profession, not only must there be the special technique but those who practise it must be bound together in formal association. That association may take the form of a society or institution by means of which the members meet together for discussion, research, and publication in their particular field, and exchange information and place at the disposal of their colleagues the results of their own experience and research. The importance of these activities which form an integral part of any professional association cannot be too strongly emphasized. They form a useful link in keeping the members of the profession together and, what is more important, they enable the members to contribute something which otherwise would not be possible. But there must be something more in common between the members than the mere desire to impart and receive information. It has been said that " A profession is not simply a collection of individuals who get a living for themselves by the same kind of work and who meet together to discuss the improvement of their technique. It is also an association of men who are bound together by rules to enforce certain standards of work and behaviour for the better service of the public."

Concern for the maintenance of standards of competence obviously implies some control over admission into the profession and the employment of methods of testing, by means of examinations or otherwise, the suitability of prospective entrants. Such control is necessary so that the public may be able to distinguish between competent and incompetent practitioners. But even the maintenance of standards of competency does not exhaust the objectives of a profession. Just as the public cannot decide upon the competence of a practitioner apart from some recognized hall-mark, so it cannot distinguish between the honourable and the dishonourable, apart from membership of the professional association. Hence a profession implies the formulation of a code of conduct to which it expects its members to adhere.

Finally, some professions aim at controlling to a greater or lesser degree the right to practise. In some cases this right is coincident with inclusion on a register, or in some cases it may be a right which is bestowed by legislation. The object of this control is to prevent incompetent practitioners lowering the standard of work which the members of the profession hold themselves out as being capable of performing.

We can now examine in the light of these requirements the organization of engineers in the I.E.E. with a view to ascertaining whether, and to what extent, it fulfils these conditions. This is still necessary even to-day because it is not yet clearly recognized by the public that engineering is a profession, and certainly it is not realized, what I hope to show is the case, that in some respects the engineering profession is ahead of others.

The primary object of The Institution is the advancement of engineering technique; in fact this was the main purpose for which it was founded. It exists (to quote the bye-laws) " to promote the general advancement of electrical science and engineering and their applications and to facilitate the exchange of information and ideas on those subjects amongst the members of The Institution." It would generally be admitted that The Institution achieves this purpose as efficiently as any other body of professional men; in fact it can be stated, without hesitation, that electrical engineers are in this respect in advance of many other professions.

ADMISSION INTO THE PROFESSION

The standard of competency laid down by The Institution for admission into Corporate Membership is relatively high, for it insists not only that the candidates shall have satisfied certain educational requirements but that they shall have had practical training and also experience in a responsible position. This demand is, in fact, more onerous than that made by some other professions of equal standing. The barrister is not required to satisfy any requirements as to practical experience. If a candidate passes the examinations (which, incidentally, are not unreasonably difficult) and eats the stipulated number of dinners, he can be called to the Bar and henceforth becomes fully qualified, though he may never have drafted a pleading or raised his voice in a court of law. His experience has to be obtained later at the expense of his clients. Many eminent lawyers and others consider that this arrangement is not altogether satisfactory. Similarly a solicitor, though he must have served his articles, which is equivalent to an apprenticeship, is not required to have had further experience, and even a doctor need not have occupied a responsible position before being admitted into the ranks of the qualified.

It is, of course, proper that engineers, before being granted the hall-mark of proficiency, should have received practical training and also have had some subsequent experience, because the essence of an engineer's training is that it should be practical as well as theoretical. But the condition in respect of subsequent experience in a responsible position sometimes bears hardly on those who may not have had the good fortune to secure a position which satisfies the definition of being "responsible." They may have had a good training, both theoretical and practical, and have passed the educational tests laid down by The Institution, but on finishing their training there may have been no suitable vacancies for them, or promotion may have been slow and they have had to be content with semi-responsible positions. That these men should be denied the privilege of Corporate Membership and thus be debarred from calling themselves Chartered Electrical Engineers is admittedly anomalous and the Council were, therefore, fully justified in deciding last year that such cases should receive special consideration.

THE RIGHT TO PRACTISE

Engineers have not yet reached the position attained by some of the older professions, notably law, medicine, and dentistry, in respect of the right to practise. Unqualified persons are not allowed to practise in the law; they have no right of audience in the courts and cannot undertake certain forms of legal work. Similarly, whilst unqualified persons are not debarred from practising medicine, they are not permitted to do many things such as the issue of certificates, which only a qualified medical practitioner is allowed to do, and a dentist must be registered before he can practise. No such restrictions exist in regard to the profession of engineering. Any person can practise as an electrical engineer and can hold himself out to be such, but not, of course, that he is a Chartered Electrical Engineer, unless he is a Corporate Member of The Institution. Membership of The Institution does not confer an exclusive right to practise. Whether engineers as a whole should endeavour to secure a monopoly similar to that possessed by lawyers and doctors, and have some form of registration, is still a highly controversial question. It would obviously require legislation and it is doubtful whether the time is ripe for it, even assuming that such an end were desirable. Attempts have been made to frame legislation with the object of protecting the title of engineer, but engineers themselves have not been united enough to bring the necessary pressure to bear on legislators, and to-day legal certification cannot be said to be a live issue. What will occur probably is that in course of time it will become obligatory for persons appointed to positions of responsibility to possess the recognized hall-mark of proficiency, and this will come about not by any legislative enactment but by the general practice of those engaging engineers. There is still considerable distance to travel before engineering reaches the same status as law and medicine, but it is gratifying to know that progress during recent years has been in the right direction and of a very appreciable extent.

LEGAL OBLIGATIONS

Like doctors, lawyers, and other professional men, engineers render service to the community by the application of their particular technique. They are, therefore, subject on the one hand to certain legal obligations towards, just as on the other they are entitled to claim certain rights from, the public.

Their main obligation is to render that service efficiently and to exercise that standard of skill and care which one expects from those who hold themselves out to be professional men. Also to display fairness, impartiality, and honesty, towards those for whom the services are rendered. If they fail in the discharge of that duty they may find themselves subject to the same penalties as the members of other professions, namely expulsion from the profession, civil liability, or even the heavier punishment which the State inflicts for gross breach of duty or for dishonesty. If they fall short of that standard of skill which one is entitled to expect from them, or, in other words, if they are negligent, they may be subject to legal liability and, if they are employed persons, they may expose their employer to an action for damages.

There are also many statutory duties to which they must conform. Compliance with the Factory Acts and the Regulations made under them is a duty which generally falls on the engineer. The development of engineering processes has greatly increased the responsibility of engineers in respect of safety in the workshop and in the power station, and recent legislation has made it still heavier. The burden falls largely upon them to ensure that machinery is not liable to cause danger, not merely to careful workmen but even to careless ones. This duty is absolute and renders the responsible engineer who fails in the discharge of it liable to a penalty, sometimes a heavy one. Not only must the machinery and plant be made safe but there must be provided a proper system of working, otherwise the person responsible or his employer may be liable if injury results. It has been held in a recent case that the doctrine of common employment does not apply where there has been a breach of statutory duty to provide a safe system of working.

The increase in application of modern engineering plant exposes engineers to risks from which members of other professions are largely immune. The types of risk are familiar to both manufacturing and supply engineers and need not be enumerated, but they are liable to lead to injury to technical engineers, for which frequently they have no redress. They are not covered by the Workmen's Compensation Acts and their claims under the common law may be defeated by the doctrine of common employment. Numerous cases have occurred in recent years of engineers meeting with serious and sometimes fatal injury without any compensation being legally obtainable. In this respect engineers are in a far worse position than the employees whom they control. This is a matter in which engineering Institutions might properly take a much greater interest, because it is one which is becoming increasingly important.

PROFESSIONAL CONDUCT

The Institution also endeavours to ensure that standards of professional honour are adhered to. Hence the formulation of a code which is, perhaps, not so well known to the members as it should be. Thus the bye-laws, following those of The Institution of Civil Engineers, provide that every member of any class, in so far as he shall be engaged or employed in any advisory or consultative capacity, shall observe and be bound by certain regulations, amongst them being that he shall act strictly in a fiduciary manner in relation to his clients. He shall not accept trade commissions, discounts, allowances, or indirect profit, in connection with the work upon which he is engaged, etc. Any breach of these regulations, if properly established, may be dealt with either by expulsion or in such other manner as the Council may think fit. This power of expulsion is another distinguishing mark of a profession, its object being that the public will come to realize that in giving patronage to the members of the professional body they are assured of honest as well as competent service.

The fact that the bye-laws regarding professional conduct are invoked so rarely by The Institution is a tribute to the general high standard maintained by Chartered Electrical Engineers.

THE AIMS OF THE PROFESSION

We have already seen that the only object of The Institution is the advancement of electrical science and engineering, but the advancement of science and engineering is not an end in itself—it is a means to an end. Its purpose is a dual one, namely, the service of the community and the gaining of a livelihood. Probably some would prefer to put the latter first in order of precedence, but those who are actuated by the true spirit of their profession will regard the service of the community as the primary objective. That, however, must not be taken to mean that an engineer's livelihood is not important. It is, in fact, complementary to the service which he renders. The desire to serve the community has always inspired the best traditions of the older professions, and it may be claimed that it has animated the best work of the engineer. But if engineers, in the exercise of their technique, are expected to render the community the best service which is technically possible, there is a corresponding duty of the community to ensure that those who render that service faithfully are honourably and adequately rewarded. Unfortunately, the public is not always alive to the importance of the function performed by the engineer, and consequently it does not pay sufficient regard to whether his services are fairly remunerated or not. Perhaps the professional Institutions are, themselves, somewhat to blame for this, in that they have not been sufficiently outspoken in claiming that engineers should be treated on an equal footing with members of other professions. It has been too readily assumed that the engineer is far above such mundane considerations and that he is so much in love with his work that he is indifferent to its pecuniary rewards. Why this notion should be so prevalent it is difficult to understand. If it is to be eradicated greater publicity must be given to the important part which engineers play and the service which they render to the public. In this connection the Engineering Public Relations Committee, which has recently been instituted, should be of service by disseminating knowledge regarding the general advancement of engineering science and by presenting, in a suitable form, information concerning the practice of engineering and its service to the public. By so doing it will help the public to appreciate the worth of engineers to the community. If the engineering Institutions exist to maintain a recognized standard of competency, industry ought to ensure that engineers obtain a return commensurate with the arduous training which they have to undergo (and in this respect few professions can make greater claims) and the responsible service which they render. Their reward should not be the lowest which they can be induced to accept in competition with their fellows, but should be sufficient to enable them to subsist under conditions of maximum personal efficiency, having regard to the powers which they possess and the functions which they perform. "We trust our health to the physician, our fortune and sometimes our life and reputation to the lawyer and attorney. Such confidence cannot safely be reposed in people of a very mean or low condition. Their reward must be such, therefore, as may give them that rank in society which so important a trust requires. The long time and great expense which must be laid out in their education, when combined with this circumstance, necessarily enhance still further the price of their labour." Those are the words of Adam Smith, the father of economic science, and they surely have an appropriate application to engineers.

ENGINEERS AND INDUSTRY

The last few years have seen in the structure of industry many changes which have had no small bearing upon the general position and status of engineers. We have moved a long way from the purely *laissez faire* policy characteristic of last century, in which individual concerns were left to work out their own plans in isolation from one another, and when the State, beyond prescribing certain minimum conditions of employment under the Factory and Mines Acts, left industry to its own devices. The amalgamation and co-ordination which have taken place, both without and as a result of State interference, have made it possible for policies to be adopted in which national benefit is of more account than individual profit, and have enabled more conscious control to be exerted over our economic life. To-day, more and more engineers are being employed in State-controlled, quasi State-controlled, or local-government service. The Post Office, the Central Electricity Board, the London Passenger Transport Board, the British Broadcasting Corporation, municipal authorities—and one might almost include the railways and statutory electricity companies, which are public utility concerns—can now claim to employ a large proportion, if not the majority, of the electrical engineers in the country. Without attempting to assess the respective merits or demerits of public service as compared with private enterprise, this tendency must be noted. Its main result is that many engineers now feel that they are serving the community more directly than was possible before these new types of organization came into being. This tendency towards co-ordination and public control is bound to continue because of the need for long-range solutions to our national economic problems, and for more efficient organization by collective action. As it proceeds, engineers will increasingly realize that in making their contribution to industry they are not only gaining a livelihood but are performing a worthy service to the community as a whole. In course of time this is bound to foster a new outlook which will have far-reaching effects upon their professional status.

ENGINEERS AND THE COMMUNITY

During recent years engineers have been made the target for considerable criticism: (1) that they are responsible for many of the economic and social evils from which the world is suffering to-day, and (2) that they are putting into the hands of men powers and instruments which they do not know how to use properly. Engineers are particularly vulnerable to such attacks because of their peculiar position in industry. In this respect they differ from doctors and lawyers. Although they perform a specialized function, they do it not as individual units in personal contact with individual clients (except in the case of consulting engineers) but as members of groups inside an industrial framework, and for and on behalf of industrial concerns, whose primary objective may not necessarily be that of service to the community but financial profit. They have not complete control over the exercise of their technique, and the rewards of their labour do not come directly from those for whom the service is performed. They are thus subject to limitations which do not press upon other professions to the same extent. The doctor is concerned solely with the health of his clients. He will not prescribe anything which he considers inimical to the welfare of those who consult him, and he will not be deterred from giving his best service or deflected from his professional ideals by the extent of the reward. The engineer cannot as a rule exercise the same control over the services which he renders, and normally he will not be concerned with the uses to which they may be put or with the consequential results of the application of the commodities which he produces. He may make an electrical machine which will provide energy for raising the standard of life of the community, or one which will fire a torpedo and liberate forces of death and destruction. When doctors associate for the advancement of their technique, they can be satisfied that human welfare will be advantaged, that healthier lives will result, and that disease will be prevented or cured, but when engineers meet to advance science and engineering they have no such assurance that mankind will be the better for their labours. Engineers make the machines, but the people who use them may do so for good or evil ends without the former having any say in the matter. Whether the results of their labours will be beneficial or harmful depends upon the general organization of society and the moral and intellectual level of those who compose it.

They are, therefore, often prompted to consider whether, and to what extent, they should seek to exert their influence in public affairs, so as to ensure that the people derive the maximum benefit from the resources which scientific technology has placed within their reach. That they cannot be entirely indifferent to what is going on in the social and economic life of the country is abundantly clear. The general structure of the economic and industrial system is a matter of vital concern to them. They find that obstacles stand in the way of the full and efficient use of their professional technique. A defective economic system or an inefficient and out-of-date financial mechanism may stultify their efforts to place at the disposal of the community cheap and abundant supplies of the commodities which the development of their technique has made possible. Whilst they are able to pour out their gifts in abundance, the social organization is not adapted to receive them. They may conceive and plan great engineering projects which would be of enormous benefit to mankind, but the execution of them may be thwarted by the conservatism of financiers or the opposition of vested interests. They may also watch with consternation the world-wide prostitution of their knowledge and skill to destructive ends, and note with growing impatience the extent to which their scientific discoveries are abused or new sources of power neglected. Must they keep silent whilst changes occur around them, and must they refrain from making their collective views heard on the larger questions of public policy which may have a profound bearing upon the effectiveness of their special contribution to society? To find the answer to this question and to discover the right relationship between scientific institutions and those who control national policy is one of the central problems of our time. It can only be solved by first having a clear conception of the place which engineers occupy and the function they perform in our national life.

Engineers are the specialists on the productive side of industry. On matters on which their special knowledge may be of value they ought clearly to have a voice, and their advice ought to be sought and obtained by those who have to settle national questions concerned with the organization of production, for example those in which the safety of employees or the public is involved, or where some social evil has arisen from the increasing mechanization of life. That they are recognized to some extent in this respect is evidenced by the consultations in regard to the problem of noise. This is fast becoming a social evil, and it is to the engineer and scientist that those in authority turn for guidance. A solution is being found, though perhaps the efforts are somewhat piecemeal. Similarly, engineers ought to be consulted to a greater extent regarding legislation designed to ensure greater safety in mines and factories.

But their special knowledge should also enable them to make a positive contribution towards increasing the efficiency of the economic and industrial system as a whole. In the past they have been inclined to confine their investigations and discussions to the improvement of scientific methods of production and increasing their own capacity as units in the productive processes. There is no reason why study should not also be devoted to methods whereby these improved processes can be made to ensure greater advantage to the community. There is a growing feeling that there has been too much concentration on the productive side and not sufficient on the consumption side of our economic system. The problems of distribution and consumption are just as capable of scientific treatment as those of production. Admittedly they may be more complex and involved owing to the human factor entering more largely into them, but they are none the less amenable to study and analysis. Distribution and consumption ought not to be at the mercy of blind economic and social forces any more than production, yet that appears to be the case at the present time. In a modern factory one sees machines with a steady current of electricity to drive them, turning out every hour and every day fixed and predictable quantities of goods, and those in control know within a negligible margin of error how many meters, lamps, motors, or other appliances, will be ready at the end of the week. Everything moves to the ticking of a clock in an orderly, co-operative effort. Outside the factory the clock ticks to no purpose. What has taken a predictable number of hours to make may wait an unpredictable number of days or weeks before it reaches a consumer, and if a financial crisis or some other extraneous event occurs, it may never reach one at all. There is order in our productive system, but the distribution system is largely abandoned to chance and is subject to alternate booms and slumps. We ought not to flatter ourselves as engineers that we have solved the problem of production and are able to produce 10 commodities for every one which our fathers could produce in the same time, if the net result is to choke the channels of distribution and make it more difficult to dispose of them. Engineers labour to achieve efficiency in production, but if their ultimate purpose is to benefit the community the true efficiency must be of the production-consumption cycle as a whole. It is futile to expend every ounce of effort to generate steam efficiently if its energy content is wasted in an inefficient turbo-generator or mains system, or to organize methods of production to the highest pitch of scientific management if the finished products are a glut on the market or if it would be ruinous to produce to full capacity. Yet that, unfortunately, often appears to be the position to-day.

What is required is the application of the scientific method to problems of distribution and consumption and, indeed, to the economic life of the country as a whole. The first step in that direction is the proper collection and organization of facts, and it is here that engineers, with their capacity to collect data and examine them impartially, can play a helpful part. Just as a scientific law cannot be enunciated without someone having amassed a great deal of scientific facts by means of patient study and measurement, so one cannot hope to arrive at conclusions regarding the improvement of economic efficiency without the application of similar methods. It is not suggested that engineers would make better economists or politicians than other people. They are probably just as liable as others to be actuated by bias in their judgment, but they should be encouraged to bring to bear upon general economic policy the same dispassionate desire for the facts as they display when solving the problems of production. It is unfortunate that many questions to-day of profound importance to our economic life have become the shuttlecock of contending political parties whose judgments are based neither on accurate and carefully considered data nor on scientific methods of deduction, but on the accident of birth or upbringing. It may not be advisable for engineers and scientists to make *ex cathedra* pronouncements on social and industrial policy or, for example, for our own Institution to attempt to voice the collective views of the members on such a question as the reorganization of electricity supply or, in fact, of industry in general, but that should not prevent them from investigating the technical merits or demerits of large-scale organization and setting out impartially the real issues involved, leaving it to others who have to settle public policy to make their decision on the facts. Because that is not done, reorganization is usually the result of a compromise of conflicting interests.

ENGINEERS AND EDUCATION

But if engineers are to make such a contribution they will need a broader type of education than is given to-day. At present there is excessive concentration on purely technological subjects without sufficient scope being allowed for tuition on those dealing with the general problems of industry. Engineering training in our universities and technical colleges is, with certain exceptions, far too specialized and narrow, and whilst it may be well adapted for producing highly sharpened and skilful tools for the industrial machine, it is not the most suitable for preparing citizens who are to understand the part which they are to play in the framework of industry and their proper relationship to others who labour within it. A student who has graduated with high honours in science or engineering may leave the university with the vaguest notions about the structure and functioning of the industrial system in which he is shortly to become a unit. He may know nothing about factory legislation or of industrial management, and may have the most elementary notions about the function of money and the system of distribution whereby the goods which are produced find their way to the consumer. It should be the aim of a university not to make him a mere technical expert, but to give him a broad view so that he will have a clearer conception of his place in the community and of the function which he is to perform in the national economic life. In this connection a passage in the paper read by Dr. A. P. M. Fleming and Dr. W. Jackson before the British Association at the Nottingham meeting last September is well worth quoting:—" The limited opportunity which present-day engineering courses at the universities afford for humane studies and for participation in the corporate life of the university is very regrettable, since these constitute two of the most important attributes of a university education. If engineers as a class are to make their contribution to the solution of the complex problems of modern communal life, it is essential that their interests be not limited to technical matters. The engineer's responsibility extends far beyond that of increasing the magnitude and scope of the production of goods and amenities; he must strive increasingly to exercise a directing influence in ordering their distribution and proper utilization. If released from technological obligations the universities could do much to stimulate in the embryo engineer the development of broader interests and participation in wider fields of activity."

We have reached the stage when it is clear that technical advance has outstripped social and economic progress. It might be worth while, and in the long run might even be profitable, for industry and the nation to allow more of its well-trained young engineers to devote time to study and research on questions connected with distribution and utilization. With their practical knowledge of workshop organization, their trained minds, and scientific equipment, they would be far more likely to find a solution for some of our industrial problems than the theoretical economist who has had no such experience of industrial life.

CONCLUSION

It is doubtful whether any profession has done more to enhance the material welfare of the community than that of engineers. They have, during the last few decades, almost turned the world upside down. They have spanned continents, put a girdle round the earth in a few seconds, multiplied productivity, and placed at the disposal of mankind benefits of which our fathers never dreamed, Compared with their achievements the strutting of statesmen and the prancing of warriors which make up the substance of our history books seem, as someone has said, " like the marshalling of tea leaves at the bottom of a cup." Men gaze in awe and wonder at the tomb of Napoleon, but who would seriously dare to say that the world has been blessed by his legacy like it has by that of Faraday. Yet Faraday is virtually unknown to the man in the street, and he and his pieces of wire and bits of iron have no special monument. Mankind does not yet realize fully what it owes to the labours of electrical engineers and other scientific workers. It is quite content to push a button and to make no further inquiry as to the research and investigation which have gone into the making of a complicated appliance, whether it be a lamp, a telephone, or a wireless set.

Happily, engineers do not seek any undue recognition for themselves. Their reward is in the labour itself and in the joy of discovery. If, however, they are to have the satisfaction of playing a still worthier part in human progress, they must adopt a less-detached attitude to those wider questions which still await solution. They must cease to think that their sphere of influence is confined to the laboratory and the factory, and must throw their weight into the scale against those tendencies which are dragging civilization down. They can do this more effectively when there is greater collaboration amongst the engineering Institutions. The partitions which divide the three types of engineering—civil, mechanical, and electrical—are really very thin and there is, therefore, all the more need for closer contact, particularly on those larger issues which affect engineers as a body. If these Institutions were linked closer together they would be able to do more for the promotion of engineering and be in a position to make an effective contribution towards the building up of a social order in which their knowledge and powers could be used for the widest possible benefit of the community. It is not without significance that in Mr. Wells's forecast of " Things to Come " the cardinal date in the emergence of a new civilization was when the conference of scientific and technical workers was held.

SOUTH MIDLAND CENTRE: CHAIRMAN'S ADDRESS

By H. HOOPER, Member.

"A REVIEW OF CERTAIN SECTIONS OF THE ELECTRICAL INDUSTRY"

(ABSTRACT *of Address delivered at* BIRMINGHAM, 20*th October*, 1937.)

> " Mystery goes out as the development
> of Man's achievement comes in."

I present to you, therefore, a retrospective and futurist review of certain sections of our industry.

In this Address I am taking the opportunity of pointing out the truth of the foregoing remark, suggesting that, through development, the mystery of yesterday has become the commonplace of to-day.

I had originally intended, and in fact had written up, a review of 12 separate sections of our industry, but the exigencies of time and your patience have resulted in this number being reduced to 5.

(1) EDUCATION

Educational facilities in the past 10 years have included:—

(1) Post-graduate research in the universities and engineering colleges as part of student training—increasing number of scholarships and grants—better equipment within the institutions—remarkable facilities in the large centres, particularly in London, for research on the part of graduate evening students. These students are very valuable material in many cases, due to academic training allied with day-time experience within the profession itself.

(2) Extension of college curricula and laboratory equipment to provide for the study and practice of communication engineering. An interesting internal development was the liaison between engineering and physics departments, particularly in the study of acoustics.

(3) Growth of e.h.t. transmission schemes in this country has already affected lecture courses in all colleges, and, to a less degree, the equipment of their laboratories. The recently founded H.T. Laboratory at Queen Mary College, London, is an excellent example of the trend in this direction.

(4) Facilities for evening students to obtain scholarships to full-time day university courses.

(5) Recognition by employers of the value of part-time day training schemes in colleges for their employees.

(6) Development by the colleges of the scheme of National Certificates in engineering.

Electrical engineering education in the next 10 years should, I feel, be dealt with on the following lines, particularly in the provinces:—

(1) Easier approach for the gifted evening student to the full-time university course. This is a matter of scholarships adequate financially to enable the student to give up his day-time employment confidently for several years, and adequate in period of time for the student to take fullest advantage of the university curriculum, and particularly of the university life. Some widening of technical college curricula is perhaps desirable to prepare students of the right type with the fundamental knowledge expected of them by the universities.

(2) Certain of the larger new provincial technical colleges are developing along university lines, and this tendency is likely to continue.

(3) Post-graduate opportunities not only for research but for higher study should increase.

(4) Laboratory instruction is at present still too restricted. Wider instruction on the power side, for example in the problems resulting from the use and transmission of e.h.t. power, and the switching and rupturing of large power, is needed, and this should be met within the next decade.

(5) Whilst keeping abreast of industrial development the universities and colleges should provide thorough grounding in the elements of engineering, which will lead to the general adoption of 4-year full-time courses of study.

(6) The most striking development should be in the courses dealing with management problems; the economics of mass production; and costing and works organization generally. It is gradually being realized that " Management " is a *science*. This will gradually extend into the field of industrial relationships (i.e. between employers and employees). A special technique and a new " profession " will develop to overcome the harshness of our present industrial system and try to bring back some of the atmosphere of the old working master with his staff of craftsmen. This new staff will deal with inducements, monetary and otherwise, factory conditions, spare-time activities, rest-periods, and anything which will help to combat the killing monotony of modern mass-production.

(7) The attempt to find a safe career, which often was so harmful to a great many boys at public schools, will not be followed in the future as in the past. If we are to go ahead in commerce, on which the whole country depends, we must send our boys into business.

[Mr. Hooper then enumerated the various Scholarships which are awarded by the Council of The Institution.]

(2) DOMESTIC UTILIZATION OF ELECTRICITY

Progress over the last 5 Years in Electric Water-Heating, and Possible Developments during the next 5 Years

About 5 years ago the idea of hiring-out electric water-heating apparatus began to become general.

This fact has had a very marked influence on the progress of electric water-heating generally.

In the early days, electric water-heating was considered possible only by utilizing the thermal principle; that is to say, all the apparatus then used consisted of large tanks in which elements of low loading were used and thermostatically controlled. The early hiring schemes used only thermal-storage apparatus working on this principle, and the capacities and loadings of water heaters were similar to those used on the Continent, whence the idea of electric water-heating first came.

As more undertakings adopted the plan of hiring-out water-heating apparatus, an attempt was made to select capacities and loadings more in accordance with the requirements of this country, and in the process of making the selection a move was made to standardize water-heating apparatus. Such things as capacities, loadings, fixing centres, shapes, etc., were, under the auspices of the Electrical Development Association, standardized in the form of a recommendation. The majority of supply undertakings worked to this recommendation in their specifications, and consequently all the manufacturers eventually made their apparatus to comply with the E.D.A. recommendations. This move began to have its effect most markedly about 5 years ago. The result was that British water heaters differed slightly in capacity from their Continental counterparts, and had higher loadings.

About this time, however, another form of water heating was coming into prominence. Immersion heaters, consisting of heating elements fitted into water-tight sheaths, were fitted to existing hot-water tanks, for use chiefly in the summer time as a substitute for coal fires. The use of immersion heaters has grown very considerably and has had a very marked effect on the development of water-heating business.

Immersion heaters have led to a change of view on the subject of loading. Of necessity, the immersion heater had to have a higher loading for the same service than would a suitable storage heater, and engineers came to the conclusion on investigating the matter that the immersion heater was not actually a " peak-load builder " as at first glance it appeared to be.

They found that the diversity in the case of immersion heaters was extremely high, and as the capital cost of installing immersion heaters was considerably lower than that of installing storage heaters, they tended to foster the development of immersion heaters as a means of heating water.

The result is that, in the 5 years under review, immersion heaters and circulators (which are the modern development of the original type of immersion heater) have become a very popular means of heating water, and the storage heater has to some extent lost ground. To-day, for instance, the greater portion of storage heater business is done in units of small capacity, chiefly 1½ gallon. These heaters are used for providing hot water for kitchen sinks, etc., and the heating of water for baths, etc., is done by immersion heaters. To some extent, development has been influenced also by the fact that modern houses do not provide much scope for installing thermal-storage heaters of the requisite capacity to meet the requirements of the household. Such houses are provided with hot-water systems which are very compact and therefore suitable for utilizing immersion heaters. In spite of general development, however, there is still considerable diversity of opinion amongst engineers in the supply industry as to the proper means for the electrical heating of water. These engineers, as the purchasers of water-heating apparatus, influence manufacturers, who find themselves in a position of having to satisfy their customers. It must be stated that the diversity of ideas has an adverse affect on development.

It is very difficult to say whether the coming 5 years will see any very marked alteration in the progress of water heating. Undoubtedly, standardization will be taken a step further and a solution will be found to the difficulties arising from variations in water regulations throughout the country. In this respect it is scarcely too much to hope that a standard will be found which will meet the approval of all water authorities.

The difficulties which are now arising in connection with hiring schemes seem to suggest that these schemes will be greatly superseded by attractive hire-purchase schemes, under which the consumer will undertake to become the owner of his own water-heating apparatus. It is doubtful whether the majority of present hiring schemes rest on a sound financial basis; in fact, in the majority of cases, it seems to be evident that some of the contribution towards meeting the capital charges involved is taken out of revenue, and this practice will not find favour with supply authorities for very long. The gas industry has for this reason almost entirely abandoned hiring schemes and substituted hire-purchase schemes instead, and the electrical supply authorities will very probably follow this lead.

The immersion heater is firmly established and seems likely to remain so, and a movement towards closer co-operation with builders seems destined to ensure that in the very near future an immersion heater will be installed in every new house. This will probably result in the sale of a very large number of small thermal-storage units to supplement the immersion heater for the heating of small quantities of water for washing and culinary purposes.

An experiment which has been tried and found to be successful in Canada and on the Continent will very probably be tried in this country in the near future. This experiment consists of offering consumers a hot-water service at a fixed annual charge, instead of charging a unit charge for the electricity consumed for the purpose. The apparatus, which is supplied and installed free of charge by the electricity undertaking, consists of a large thermal-storage heater with an element of very low loading, which is thermostatically controlled. Owing to the exceptionally low loading, the supply undertaking is able to provide the electricity at a very small figure indeed per unit, and the annual charge is arrived at merely by calculating the total current which a typical consumer is likely to absorb, and adding to the cost of these units an increment which covers the capital charges on the apparatus. (A somewhat similar scheme is being tried out in a London borough.)

To deal with the problem of occasional heavy demands, a booster element is installed which is hand-controlled, and the electricity supplying this element is metered at the ordinary charges.

In Canada, particularly, the scheme has been found to be financially successful, and the attraction to the consumers has been so great that development has been very rapid indeed. It would appear that such a scheme would also be very attractive in this country, and no doubt investigations into the possibility of such an experiment will be made within the next five years.

There does not seem to be any indication that water-heating apparatus itself will undergo any marked change in the near future. The components are gradually being made more reliable, but development seems to take place along evolutionary lines rather than by the occasional discovery of a revolutionary method.

(3) ELECTRIC DISCHARGE LAMPS

In this field there has been noteworthy development. Many years ago mercury-vapour lamps were utilized for factory lighting, but the improved vacuum-type lamp retarded experiments in this direction.

Principal recent developments are:—

1932—This year saw the most noteworthy advances in electrical discharge sources of light since the neon advertising signs of 1932, and experiments were made in street lighting.

1933—At the beginning of this year there were in England three street-lighting installations using electric discharge lamps, at Wembley, Croydon, and Ilford. The installations at Wembley and Ilford used high-pressure mercury lamps, and the one at Croydon employed sodium-vapour lamps. Research and developments were carried out under the headings of construction, characteristics, and utilization.

1934—Early in 1934 there were approximately 2 000 street-lighting standards equipped with electric discharge lamps, roughly equivalent to 70 miles of roadway.

1935—Higher-pressure lamps and luminescent powders were commercially practicable.

1936—Approximately 30 000 street-lighting posts in the British Isles were by 1936 fitted with electric discharge lamps, equivalent to 1 000 miles of highway.

1937—Higher-pressure mercury-vapour lamps did not appear as commercial articles (though expected in 1936) until 1937. The number of street-lighting posts in Great Britain using discharge lamps by the end of the year will probably be 60 000, equivalent to some 2 000 miles of highway, and by the end of the year there will be in Birmingham 3 634 electric discharge lamps covering 157¾ miles of public lighting and costing £86 259.

Future.—In the design of general-service lamps the tendency is towards higher vapour pressures, which naturally yield higher efficiencies. The application of this type of lamp in the higher-wattage range will, however, be limited owing to the extra auxiliaries required, e.g. the need of water-cooling.

It is interesting to see what range of brightnesses is in prospect, and to review the brightnesses which have been characteristic of past light sources. The brightness of the first electric lamp, namely the carbon lamp, was in the region of 60 candles per cm.^{2} whilst the vacuum lamp, which succeeded it, had a brightness of some 150 to 160 candles per cm.^{2} The gasfilled tungsten filament lamp, with a clear glass bulb, had an average brightness of 800 candles per cm.^{2}

In the case of the ordinary 25-ampere carbon arc, the brightness is usually in the region of 19 500 candles per cm.^{2} while with high-current-density arcs values up to 50 000 and even 80 000 candles per cm.^{2} are obtainable. In the electric discharge-lamp field the brightness of sodium is 10 candles per cm.^{2} and in standard mercury-vapour lamps with pressures of 1 to 2 atmospheres it is about 160 candles per cm.^{2} The new higher-pressure mercury lamps of 80 watts or 125 watts give brightnesses of about 800 candles per cm.^{2}

Working at still higher pressures and overloading these lamps, the brightness can be increased to 1 700. Of course this reduces their life, but not to such an extent as to render them impracticable for projection uses. Their life in these circumstances is dependent upon the devitrification of the quartz envelope which occurs at high temperatures.

If, however, the quartz tube is water-cooled, the loading may be very greatly increased, and then brightnesses of 25 000 candles per cm.^{2} can be obtained with a life of the order of 50 to 100 hours. If the loading is increased still further, almost to the limit, a brightness in the neighbourhood of that of the sun, 180 000 candles per cm.^{2} can be obtained, but only for a very short time. The pressure is then 300 atmospheres, and even with water-cooling the quartz is liable to disintegrate rapidly. I am unable to forecast when such lamps will be ordinary market products.

It has long been known that the eye operates most efficiently at illumination levels far above those used in practice to-day, but the increasing efficiency of light sources will make it possible to provide much higher illumination values economically.

I am convinced that the reduction in the cost of light will mean that the public will utilize more light for the same cost rather than the same amount of light at a lesser cost, and therefore in the future there should not be any excuse for damage to eyesight through the effects of poor illumination.

It seems to me that these developments must have an outstanding effect on the whole art of lighting, which, starting with an outdoor and industrial application, will spread gradually to the commercial and domestic spheres.

I consider that one of the greatest outlets for illumination development will be in respect of our roads. Each day 1 000 new motor-cars make their maiden trip on British roads. Traffic since before the War has increased by 1 000 per cent, while roads have increased by less than 5 per cent.

One in three fatal accidents on the roads happens in the dark. It would cost approximately £3 500 000 to light the main arterial roads of Britain. This may seem a large sum, but think of the amount paid out in compensation for those killed.

Twelve months ago the then Minister of Transport said that there was practically universal approval for the plan to light the main roads, but it does not appear that much has been done in this direction.

Great Britain has made phenomenal progress in the application of the electric discharge lamp to street lighting and industry during recent years. As far as street lighting is concerned, there are already 1 500 miles of main traffic routes lighted with electric discharge lamps, the total of which surpasses the use of electric discharge lamps for street lighting in the rest of the world. At the present time we are leading even the United States. Although there are some outstanding examples of street lighting practice in Chicago and on the San Francisco Bridge, there is no town which has tackled the problem fundamentally in the same way as Birmingham. Here the street lighting of the whole of the main traffic routes in the city has been revised in accordance with modern standards.

(4) CABLES

Underground Transmission Cables

The most notable achievement in the development of high-voltage cable is the way in which oil-filled cables have progressed. In 5 years the 132 000-volt cable has passed from the experimental stage to the developed commercial stage.

High-voltage cables, by which we now mean those working at 66 kV and over, are extensively used in the Central London section of the grid.

97 circuit-miles of 66-kV cable are used in that area, and 43 circuit-miles of 132-kV cable. 63 circuit-miles of the 66-kV cable are of the so-called solid type, and all of these are single-phase. The remainder of the 66-kV cable is oil-filled, and the latest sections, comprising 34 circuit-miles, are of the 3-phase type.

With the exception of 1 circuit-mile of internal-gas-pressure cable, all the 132-kV cable is of the oil-filled type, and all is single-phase.

The experience obtained with these high-voltage cables, which extends back to 1930, and the loads transmitted, show that the 66-kV types at least are now completely out of the experimental category and may be accepted as reliable parts of a power transmission system. Some reservation must still be made with respect to 132-kV cable, but the time is rapidly approaching when it too can be accepted as a standard commercial article.

The technical experience and investigation behind this prosaic statement of the facts are of an involved and fascinating nature. They must, however, be left to cable and insulation experts. The lesson of experience appears to be that the old-fashioned solid type of dielectric does not meet the requirements for high-voltage work and that special construction, such as oil-filling and internal or external gas pressure, are essential to ensure the high degree of freedom from failure which is now a necessity in electricity supply.

To-day we have more cable makers equipped for oil-filled cable manufacture than any other country in the world, and we may claim for this country at least 50 % of the world's total of over 1 000 miles of oil-filled cable installed.

The successful way in which these cables have overcome ionization by eliminating internal voids in high-voltage cables has encouraged designers to develop a number of alternative types—chiefly with a view to eliminating the oil tanks and accessories along the routes of such cables. Of these the most successful so far has been the gas-pressure cable in which a solid-type cable is drawn into a gastight steel pipe and subjected to a high external pressure by nitrogen gas. The expansion and contraction of the lead sheath of this cable are under the control of the gas pressure, and in order to assist this action the cable is made in triangular section with flat surfaces upon which the gas pressure acts. The merit of this type is that it only requires gas-pressure pumps and containers at one end of the route, but the disadvantages are that the cable must be put out of commission if the gas pressure falls, and gas leaks are extremely difficult to locate. Instances have occurred where gas leaks have developed and have not only been extremely difficult to locate but have caused excessive trouble to repair.

There is no doubt, however, that in spite of the progress that has been made—and we may claim that our cable makers are abreast, if not ahead, of world development—there is going to be still greater progress in the very near future, and I have no difficulty in foreseeing underground cables operating at twice the highest voltage at present in use in this country. One well-known firm of world-wide reputation has developed a cable which is being tested at the equivalent of 260 000 volts between phases, and this is giving excellent results on test.

Coaxial Cable

Special reference must be made to this development.

The coaxial cable laid between London and Birmingham, and Birmingham and Manchester, consists essentially of four concentric cables of a special type, each being lead-sheathed. The four cables, along with a number of independent conductors of ordinary type to act as pilot circuits and as a packing between the four concentric cables, are enclosed in a lead sheath. Externally, therefore, the coaxial cable is identical with any other telephone cable of similar size.

The concentric cables are designed to have as low capacitance as practicable, the insulating material (catopa) being kept to a minimum to reduce losses and having a specific inductive capacity near to unity.

Owing to the concentric nature of the cables they are self-screening in character, and permit the high amplification which is necessary without exceeding the allowable amounts of cross-talk from cable to cable.

It is hoped that frequencies up to 3 megacycles will be transmitted, reversed feed-back amplifiers being installed every 7 miles. This should allow of the use of the cable either for a large number of separate telephone channels or for the wide band of frequencies necessary for the transmission of television.

The latter problem is rather different from the former, since, although it does not require the apparatus for splitting the band of frequencies accurately into a large number of parts, it does require that the phase distortion which naturally exists should be properly corrected.

Considerable progress has been made in both these directions.

Ultra-long-distance Power Transmission

There are inevitably many millions of natural horse-power going to waste in various parts because the power is too far from centres of commerce to be transmitted efficiently and commercially at present.

It is useless attempting to transmit to great distances unless the charge per unit due to interest and sinking-fund charges on the line is down to about 0·02d. per unit. Great powers per circuit have to be transmitted, and this introduces instability.

Surely, in the future, where a high natural head of water is available (keeping down dam charges) we can look forward to the commercial possibility of transmitting power up to, say, 1 000 miles.

The difficulties to be overcome cover such problems as raising the voltage to such a value, combined with such an amount of power per circuit, that the interest and sinking-fund charges on the towers, insulators, and synchronous condensers, do not bear too high a value in relation to the necessary waste of power in the line itself, bearing in mind that the line I^2R losses diminish as the square of the voltage, while capital charges on condensers increase approximately as the cube of the voltage.

The problem of the future in connection with ultra-long-distance power transmission appears to me to be one of relationship between the cost of condensers and the combined problem of maximum voltage and current density.

(5) ELECTRICITY SUPPLY

Public Enterprise

The Institution is above all politics, and the following remarks are not intended to have any political bearing whatever.

Public bodies entrusted with the operation of vital public utilities and the regulation or organization of great national industries have been set up in this country during the past 30 years, and especially in the last decade. It is impossible to overestimate their importance in the economic and social life of the community. They form the most significant development in the field of political institutions which has taken place in Great Britain during the present century, yet, curiously enough, they have not received systematic attention from social scientists or publicists.

In the first place, one could rightly say that the Post Office represents the traditional method of organizing a social service, and, in the second place, the consumers' co-operative movement is the other great and alternative method of producing and distributing goods and services without profit to the producers.

A collection of studies of the workings of the above examples with the addition of, say, the Port of London Authority, the British Broadcasting Corporation, the Central Electricity Board, the London Passenger Transport Board, the Agricultural Marketing Board, the Coal Mines Reorganization Commission, and the Forestry Commission, would produce so many angles of different political philosophies that the issue would be more confused than clarified.

Yet is it not the old story that the failure of evolution produces revolution? In typically British fashion, public utilities have grown up, not based on any clearly defined principle, but evolved in a somewhat haphazard manner.

Politicians of every creed, when confronted by an industry or social service which is giving trouble or failing to operate efficiently, almost invariably propose the operation of an independent Public Board. The idea appeals equally to the right and to the left. The Central Electricity Board was set up by a Conservative Government, and the Labour Party holds the view that a similar type of control will be required for the operation of most industries when socialized.

Whether one likes it or not, the Public Service Board has made a deep impression among politicians of all parties, but, despite this newly awakened interest, neither politicians nor the general public know very much more about the existing examples than they did 5 or 10 years ago.

The Supply Side of our Industry

I do not propose to weary you with an historical survey of the origin of the electricity-supply industry, but will commence from the 1926 Act.

To overcome some 30 or 40 years of more or less haphazard development in generation was the work of the Central Electricity Board following the passing of the 1926 Act. Since then, thanks largely to the efforts of the Electricity Commission and the Central Electricity Board, a material change has taken place and considerable progress recorded.

Interest and controversy are now acutely raised by the publication of the Report of the Committee on Electricity Distribution in May, 1936 (the McGowan Report), followed by the issue of the Government White Paper on "Electricity Distribution—Outline of Proposals, 1937." You should all be aware of the reasons for this Committee being appointed in July, 1935, and its terms of reference, but these terms may be worth repeating:—" To bring under review the organization of the distribution of electricity, including the control of statutory electricity companies by other companies, to advise on methods by which improvements can be effected with a view to ensuring and expediting the standardization of systems, pressures, and methods of charge, further extending facilities (including supplies in rural areas) and reducing costs, and to make recommendations."

Viewed as a future prospect with all its possible controversies, the objects of this report seem difficult of attainment, but I would remind you that great events vary so much in perspective when it is possible to view them as past history.

There is a vast difference between the administration of electricity supply for the public and the selling of electricity as a commercial commodity, and different viewpoints about a definite public utility will sooner or later lead to action being taken to consolidate or clarify the position.

I hold that failure to discuss critical situations openly does harm. I am not proposing to put before you the merits or demerits of the contending parties, who quite naturally hold dear their individual rights and do not intend to lose " birthrights for messes of pottage."

I venture to suggest, however, that, great as the present controversy appears to be, it will sink into historical insignificance with the advent of the greater and major problem of the future, i.e. the question of complete control or otherwise. We all know the question is there, so why shrink from its responsibility ?

The future of the electricity supply industry is, in my opinion, entirely wrapped up in this major question. What can one say about it ? I give below some of the points which have been put forward by interested parties.

Ownership and control as at present.

(1) The profit and loss accounts of undertakings receive individual and concentrated attention.

(2) Mutuality of interest between undertaker and consumer is established, and this is based entirely on local knowledge and experience. Especially has this been so on the power side, and now this experience, based on intimate association, is building up the domestic load.

(3) All statutory obligations have been observed and duties carried out with skill and ability; the value of this " goodwill " is as definite as the goodwill of other types of business.

(4) Charges made against the financial methods adopted by certain undertakings affect only the relatively few, and to impose a central control of finance on the whole industry would be grossly unfair to the great majority of undertakings, whose generally-adopted principles in finance are beyond reproach and are for the best interests of the industry.

(5) Tariffs are rapidly becoming more uniform, but the ideal of a universal and equal tariff is not one of practical attainment.

(6) The possibility of the compulsory acquisition of one undertaking by another without adequate goodwill benefit may tend to hamper development.

(7) It is not correct to assume that electricity supply is a monopoly. Competition with gas, private plants, and oil, was never keener, and consumers never benefited more. Individual attention and local knowledge were never more essential to progress.

(8) Enforced control would be difficult to work in Great Britain, besides adding heavy costs to the industry.

(9) Due to competition, there is no danger of overlarge units of management being allowed to suffer from " red tape."

(10) Much development work, unremunerative for years, has been shouldered by existing undertakings.

(11) There is nothing fundamentally wrong with the supply industry, and it should be left alone to work out its own distribution and sales problems by co-operation with other undertakings and the Electricity Commission.

(12) Further control is unnecessary, as the industry is admittedly progressing very satisfactorily.

(13) With competition from other sources of power, it is essential that full negotiating power should be in the hands of the man on the spot, which procedure would be hardly likely under national control.

National control.

(1) Co-ordination of a public utility and universality of policy.

(2) Compulsory standardization of supplies would be a policy more readily achieved.

(3) Collective use of technical information.

(4) Standardization of domestic apparatus, and, in consequence, better facilities for purchase, together with economic production.

(5) A greater uniformity of tariffs for industrial and residential districts, and better and possibly cheaper facilities in the country districts.

(6) Standardized terms for assisted wiring, and hire and hire-purchase of apparatus.

(7) Unification of ownership would contribute to the success of nationally-planned generation. For distribution, which has even greater claims for national planning, unification is even more vital and urgent.

(8) A national policy would be better than dealing with the industry by successive stages.

(9) A more rapid acceleration of the development of rural areas is likely to take place, extending to the countryside standards of life which previously had not been available.

(10) More satisfactory lighting of national highways would, no doubt, be probable.

(11) Electricity supply is one of the key industries eminently suitable for national ownership and control, and the national defence policy demands control of all vital services.

(12) The grid, which has proved its worth as a method of consolidation and control of generation, is a development of significance, but only represents the traditional British compromise between extremes.

(13) Existing distribution based on the areas of local government has no relation to electrical requirements.

(14) The consumer is the shareholder. The system of developing an undertaking by means of loans repaid by the consumer will give the consumers maximum benefit when the loans are paid off.

(15) With public ownership the reward of capital is service to the consumer. With the company, the reward of capital is dividends for the shareholders.

(16) The security of the rates generally enables a public body to obtain money for capital at the lowest rate of interest. Current could therefore be supplied at a lower price to the consumer, and this should be the first consideration.

(17) Public ownership ensures greater interest by the consumers as they are the real owners; therefore they look for no other reward than good service. There is no incentive for personal gain, which is the case under private ownership. The ideal consideration is to provide electricity in the homes as freely as water and other health services, and, as these are a rate charge, electricity should eventually be the same.

CONCLUSION

Individual initiative and effort will always be the source from which changes are derived, but their ultimate values will be strictly in accordance with the measure of rational control exercised in shaping them to the needs of the community as a whole.

Is it too much, therefore, to hope that any scheme or schemes being brought forward now, or likely to be brought forward in the future, the object of which is to assist in the development of this most beneficent public utility and general need, viz. electricity supply, will be examined from the viewpoint of the general good ?

That criticism may be worth anything, a critic must have high standards, and that is the final thought I would leave with you.

NORTH-EASTERN CENTRE: CHAIRMAN'S ADDRESS

By W. D. HORSLEY, Member.

"THE GENERATION OF ELECTRICAL ENERGY"

(ABSTRACT *of Address delivered at* NEWCASTLE-UPON-TYNE, *25th October*, 1937.)

INTRODUCTION

There is no natural store of electrical energy; it is made available only by conversion from some other form. The modern electric power-generating station is based on two prime factors—the heat engine and the electromagnetic induction machine. They have both come to be accepted as indispensable components, and every effort has been made during the past 50 years to develop the system to its utmost.

EARLY GENERATORS

In 1831 Faraday discovered the principle of electromagnetic induction and thus laid the foundation stone of the most important social service of the modern world. The history of electromagnetic generation of power commenced at that date.

The early generators following Faraday's discovery gave an alternating current, but as soon as the commutator was introduced direct-current generators were developed and the alternating-current generator was for the time being relegated to the background.

The first direct-current generators gave a pulsating, or, as it was then called, a uni-directional current. A steady voltage was obtained with improvements in armature construction. The ring armature which was invented by Gramme was an important advance, and the generator became of industrial and commercial value. The drum armature, which is the form used to-day for d.c. machines, followed shortly afterwards.

It was not until the Jablochkoff candle was invented in 1877 that an alternating-current supply appeared to have any advantages; various designs of alternator were then evolved.

Gramme constructed an alternator with a stationary armature in 1878, but the majority at this time were of the revolving-armature type. The construction was usually similar to that of direct-current generators, with slip-rings in place of the commutator. Low-speed revolving-field salient-pole alternators were developed about 1885.

A.C. and D.C. Supply Systems.

The load for the early electric supply systems consisted mainly of lighting, and both alternating and direct current were suitable.

A fierce controversy raged for many years round the respective merits and demerits of the two rival systems. From about 1890 onwards, as the size of electric power systems increased, the alternating-current system made greater headway. A high voltage is necessary for the economical transmission of electrical energy over even comparatively small distances. The transformation from a high voltage to a lower voltage for distribution, and again to a lower voltage for domestic consumption, is readily accomplished by means of an alternating-current transformer, which constitutes one of the greatest advantages of the alternating-current system. There is no direct-current apparatus for voltage transformation comparable in simplicity or efficiency with the transformer.

The direct-current system had a number of serious limitations. The direct-current generator, in striking contrast to the alternator, is limited in output, voltage, and speed. The brushgear and commutator of a direct-current machine require considerable maintenance, while their reliability is not equal to the standard of other parts of the plant. The difficulties of commutation limit the output of a direct-current machine to a value far below that required by the economics of generation.

When motors were first used for domestic and industrial purposes a direct-current supply was favoured on account of the flexibility and wide range of speed control of the d.c. motor. The single-phase a.c. motor of that time had poor starting characteristics.

In some of the early supply systems the advantages of the a.c. system were combined with those of direct current by the use of motor convertors and later by rectifiers. Development in a.c. motors and other apparatus for the utilization of electrical energy has been rapid and the use of direct current has declined.

In 1890 the effects of reactance and capacitance and the general phenomena of an alternating current appeared very complex. These were, however, minor factors compared with the importance of economy of generation, transmission, and distribution. The ultimate triumph of the a.c. system was inevitable.

THE TURBO-GENERATOR

Prior to the introduction of the steam turbine, the speed of existing prime-movers was too low for the economical design of generators, which were therefore usually driven by means of a belt in order to raise the speed to a suitable value.

The steam reciprocating engine is restricted to a low speed of rotation and is not suitable for large outputs on account of its massive proportions, nor is it capable of a high fuel economy.

The steam turbine has none of these limitations and has made possible the generation of electricity on the scale it has reached to-day.

The progenitor of the modern turbo-alternator was born in 1884, when Sir Charles Parsons constructed his first turbo-generator. The steam turbine, being essentially a high-speed machine, appeared to be admirably adapted to the driving of electric generators, but the most efficient speed of a small impulse turbine wheel was outside the limit of general practical use, and the object of the Parsons compound steam turbine was to reduce the economical speed to a reasonable figure.

The speed of even a compound steam turbine of the comparatively small output contemplated for the first machine was still high in comparison with that of the usual design of generator of the period, and so the difficult problem of designing an unusually high-speed generator had also to be faced.

The construction of this generator was in itself a splendid achievement, more especially as the principles of dynamo design were only beginning to be established at that time.

As the design of the compound steam turbine advanced and the size of machine was increased, the speed of rotation was reduced. The design and construction of high-speed generators and alternators also improved, and an ideal combination rapidly became established.

The development of the compound steam turbine was singularly opportune, for it coincided with the birth of public electricity supply systems in 1882. Swan developed his electric lamp about the year 1878.

The first turbo-type alternators were similar in construction to the early turbo-generators, again with the simple substitution of slip-rings for the commutator. These alternators were built in 1889 for the Newcastle and District Electric Supply Co., Ltd., and had a capacity of 75 kW at 1 000 volts. They were single-phase and ran at a speed of 4 800 r.p.m., giving a frequency of 80 cycles per sec. A large number of machines of this type were built by Parsons in the next decade for various supply stations.

As output and voltage increased, the limitations of the revolving-armature construction were soon reached. These difficulties increased with polyphase windings owing to the crossing of the phases in the end-windings, which caused breakdown of the insulation at these points. The salient-pole alternator with stationary armature was next evolved, but mechanical difficulties with the rotor soon became another limitation. In 1901 a fundamental advance was effected by Charles Brown, who introduced the cylindrical or barrel-shaped rotor.

The first cylindrical rotors were built up of thin laminations, and the end windings were carried in slots punched in the periphery. In later designs, cylindrical rotors were built up with boiler-plates and the winding slots were machined.

The next important advance was made in 1911 when a single-piece solid forging was used for a high-speed rotor, a construction which is almost universally adopted to-day for large high-speed rotors. Every precaution is taken to ensure that a forging is sound, and rotor forgings up to 70 tons in weight have been successfully manufactured.

The main objects in the design of a turbo-alternator rotor are simplicity and robustness: the number of individual parts is kept to a minimum and no castings are used. The soundness of all material is most carefully tested.

In alternator stators, cast-iron stator casings have given place to welded structures, the hysteresis and eddy-current losses in stator cores have been much reduced by the use of silicon-steel plate, while methods of core-punching and core-building have been much improved. Many improvements have also been made in the details of construction and manufacture of windings.

The stator-conductor insulation of the early machines consisted mainly of press-spahn and other fibrous materials. In the first turbo-type alternators to be built for 11 000 volts, supplied by Parsons to the Kent Electric Power Co. in 1905, the thickness of the stator slot insulation was nearly $\frac{1}{2}$ in.

Many changes in insulation have been made since that date, and the thickness of the slot-tube of a modern 11 000-volt winding is less than $\frac{3}{16}$ in. The main constituent of modern insulation is mica; the insulation is built up of mica flakes with a varnish bond.

Continual research has resulted in considerable advance in insulation practice, and while an ideal insulation has not yet been found the modern article is reliable and satisfactory.

Alternator Characteristics.

The characteristics as well as the design of alternators have changed considerably during the last 30–40 years. In the early days of supply systems and of the turbo-generator, the load consisted mainly of lighting; the frequency of an a.c. supply, and therefore the speed of the turbine, were not of the first importance. In practice, the speed of many early machines was fixed finally on the test-bed, and the turbine was tested over a range of speed in order to determine the speed which gave the best steam consumption. The field-magnet system of the generator was modified if necessary, to suit the speed finally adopted.

There were also occasions in the early history of the turbo-alternator when it was found expedient to adjust the speed of the set in order to obtain the correct voltage.

As the lighting load developed and the incandescent-filament lamp found a widening market, it was important to have a constant supply voltage. Various methods of maintaining constant voltage were investigated.

Voltage Regulation.

It is interesting to recall that the first turbo-generator was provided with a form of automatic voltage regulation. The method adopted was ingenious and was later applied to both generators and alternators. A fan was mounted on the turbine spindle which exhausted air from a leather bellows. The latter was attached to the levers operating the main steam valve in such a manner that the bellows when exhausted of air closed the valve against a spring. The vacuum in the bellows could be varied by a varying leakage of air into the bellows. The leakage was controlled by an iron armature mounted upon the top of the generator field magnets. The position of the armature and consequently the amount of air leakage into the bellows was governed by the strength of the magnetic leakage flux from the magnets, which in turn was approximately proportional to the generator voltage. A fall in voltage increased the air leakage into the bellows, causing the valve to be opened and more steam to be admitted to the turbine. The speed was thus increased until the voltage again reached the normal value, and conversely a rising voltage was corrected by a fall in speed.

Various forms of this type of voltage regulation were devised. The most usual form consisted of a solenoid excited from the machine terminals and arranged to control the turbine governing valve through an electrical or hydraulic relay. A compounding winding was sometimes fitted to the solenoid.

This form of governing had the unusual characteristic of a rise in turbine speed with increase in load. It was impracticable to run in parallel, machines governed in this manner. The need for parallel running was not strongly felt in the early days of electrical supply, and each machine was arranged to supply its own group of feeders. A rapid switch-over was necessary when changing machines. There are alternators of this period with the type of governing described running in this district to-day.

At one time many engineers thought that it was impossible to run alternators in parallel: this was soon disproved and speed-governing independent of voltage control became essential.

The most suitable form of governing was found to be the centrifugal type, and it is still in use to-day. With this type the speed falls with increase in load and there is no difficulty in load-sharing with machines operating in parallel.

Inherent Regulation.

Lacking external automatic voltage regulation, the inherent voltage regulation of a machine was of great importance. For many years supply engineers specified close inherent regulation of alternators, and it was not unusual for the rise in voltage in throwing off full load to be as low as 3–4 % at unity power factor and 10 % at 0·8 power factor. The corresponding figures for a modern alternator are 35 % and 50 %.

The close regulation demanded by operating engineers in the early days of electrical generation was difficult to obtain. Alterations to field magnets, air-gap, and even the number of armature conductors, were often necessary after testing. The calculation of the magnetic circuit was difficult and it was not uncommon practice to design the field coils after a machine had been tested.

One of the main disadvantages of close regulation was that it was accompanied by low reactance of the alternator. The current on short-circuit was high, with consequent danger of movement and damage to the windings. The disadvantage of a high short-circuit current was appreciated as early as 1894, although short-circuit phenomena do not appear to have been clearly understood at that time.

In order to overcome the difficulties of close inherent voltage regulation of alternators, many attempts were made to devise a satisfactory form of compounding. Good regulation can be obtained from a d.c. machine by the simple addition of a series compounding winding. It was found possible to apply this method to alternators, using rectified load current in order to augment the main rotor current or the exciter field current. An ingenious form of compounding, called the "leakage path device," was used by Parsons in 1905. In this the output of the exciter was modified by means of unrectified alternator load current. Whilst both these methods of compounding gave a reasonably constant voltage with varying load at constant power factor, they did not compensate for changes in the power factor of the loads.

Various attempts were made between 1900 and 1905 to devise satisfactory means of compensating for changes in power factor. One method was to supply an alternating current proportional to the load current to a special winding in the exciter armature which ran synchronously with the generator. The special winding gave a magnetizing effect which increased at lagging power factors. In another method a special construction of the alternator rotor was employed; this arrangement gave an uneconomical design and has not survived.

Automatic Voltage Regulation.

As power systems grew and both lighting and heavy fluctuating industrial loads were supplied from the same source, voltage regulation became essential. The idea of inherent regulation appealed to engineers, as the number of individual pieces of apparatus was kept to a minimum. It was found in time that external voltage control was more accurate and less expensive than methods of compounding alternators.

Rheostatic automatic voltage regulators operated from a solenoid or relay connected to the terminals of the alternator or to the supply network and incorporating line-drop compensation were proposed as early as 1894. The vibrating-contact and torque-type regulators appear to have been introduced about 1905, but were not in common use until some years later.

With the general adoption of automatic voltage control, close inherent regulation of alternators became unnecessary, and so a serious limitation to alternator design was removed. It was then found possible to increase the amount of armature reaction without exceeding the recognized temperature limits, with the consequent advantage of increasing the inherent reactance of the alternator. The short-circuit stresses imposed on the stator windings were thereby reduced, and the duty imposed on switchgear under short-circuit conditions was lessened.

Stability.

In recent years the alternator has become more closely associated with the transmission system than with the distribution network, with which it was associated in the past. Transmission systems have grown more extensive and more complicated. Many characteristics of alternators which at one time were comparatively unknown have become of importance to operating engineers.

The characteristics of the alternator have an important bearing upon the stability of operation of large systems, both during normal service and under fault conditions. Instability may occur owing to a variety of causes, some of which are entirely dependent upon inherent properties of the alternator.

A deep study of the alternator is necessary in order that problems of this nature may be fully understood, and a considerable amount of work has yet to be done in this direction. Investigations have shown that, amongst other factors, automatic voltage regulation in conjunction with adequate excitation voltage response is an important factor in maintaining stability. High excitation response does not necessarily require a high excitation voltage or super-excitation; the latter is only required for special machines or special operating conditions.

Alternators are normally required to be designed for operation at a lagging power factor; owing to the more extensive use of interconnecting cables and overhead lines the capacitance of transmission systems has greatly increased, and the power factor of the load has also improved owing to the greater use of apparatus for power-factor correction. Alternators are therefore frequently required to operate at unity or at leading power factor.

The amount of leading kVA that an alternator is capable of supplying under various load conditions is of importance to operating engineers. At no-load the amount of leading kVA is limited by self-excitation of the alternator, and at the maximum load by the heating of the alternator stator windings. At intermediate loads the maximum leading kVA is determined by the pull-out torque of the alternator.

The advantage of a high alternator reactance in limiting the current on sudden short-circuit has already been mentioned. The reactance is not a constant value and varies according to whether the machine is on load or short-circuit and whether it is operating 3-phase or single-phase. In order to be able to predict or analyse the performance of the alternator it is necessary to have an accurate knowledge of the reactance under all conditions of operation. The time-constants of the various electrical circuits in the alternator have also to be known.

The distribution of inductance and capacitance in the windings is of importance in determining the behaviour of the circuit when subjected to voltage surges.

The presence of ripples in the voltage wave-forms of alternators has occasionally given rise to difficulties with telephone interference. The modern turbo-alternator has a voltage wave-form which approaches closely to a sine wave, the harmonics usually being of the order of less than 1 % on open-circuit. It is impracticable to obtain a pure sine wave, and in order to avoid telephone interference it is essential to have proper co-ordination of communication and power circuits.

Generating Voltage.

The increase in the size of generating stations and units in recent years has brought about higher generation switching voltages. This change has been largely due to the inherent difficulty of constructing switchgear of high breaking capacity for low voltages and heavy currents. Generating voltages of 36 kV and higher are now common. The higher generating voltage may be obtained by means of a low-tension alternator and a step-up transformer, but direct generation is more economical and has the advantage of eliminating heavy-current leads between the alternator and transformer.

The first turbo-type 36-kV alternator was constructed by Messrs. C. A. Parsons and Co., Ltd., and commissioned in 1928. Since then high-voltage alternators have been used extensively and their reliability is proved. The concentric-conductor type of alternator has many advantages. It has a high efficiency, and its high inherent reactance limits the current on short-circuit. It is inherently protected against voltage surges owing to the large capacitance of the windings to earth and to an ideal distribution of capacitance and inductance between turns.

The concentric-conductor high-voltage alternator is an outstanding development of recent years and a notable exception to the present rule of gradual change. Its conspicuous success is, however, due to many years of careful preliminary investigation and research on every detail of the new construction.

Reliability.

The main lines of development of the turbo-alternator have been the construction of larger units and an increase in the output per unit weight of material.

While making every effort to reduce the cost of generation by these means, the primary consideration of the manufacturer has been to maintain and improve the reliability of the unit.

The design of the turbo-alternator has now been established for a number of years, and many data have been accumulated upon which future designs can be based. What seems simple to-day was only made so by years of effort in the face of great obstacles. Sir Charles Parsons, in some of his earlier papers, well describes the trials and tribulations of the pioneer. He remarks " How difficult is any step of advance when shrouded by unknown surroundings "—a statement particularly applicable to the early history of the turbo-alternator, when many major changes in design and construction had to be made. A certain amount of progress can be made in the works laboratories and test shops, but in heavy engineering this is not enough, and a full-scale experiment on an actual machine is often the only method of advance. It is difficult to appreciate what this meant in the early days of power generation.

Size of Units.

As the output and speed of a turbo-alternator is increased, the capital cost per kilowatt is reduced while the steam consumption is also less.

A single unit occupies less space than two or more units of the same total output. This is an important factor where the land is valuable; in addition the cost of buildings and foundations may be reduced.

The development of the turbo-alternator has therefore been characterized by a steady growth in the size of single units running at the maximum speeds.

In Great Britain the largest single turbo-alternator is rated at 100 000 kW and runs at 1 500 r.p.m.; up to the present outputs at 3 000 r.p.m. have been limited to 40 000 kW on account of turbine exhaust restrictions for British vacuum conditions. Units of 50 000 kW at 3 000 r.p.m. are being built for South Africa and Australia, while on the Continent a few machines of 60 000 kW at 3 000 r.p.m. have been installed.

The largest single unit in the world is probably the 160 000-kW (183 000 kVA) 1 800-r.p.m. turbo-alternator installed in the Richmond power station of the Philadelphia Electric Co.

In this country the use of electrical energy continues to increase at a satisfactory rate, and in order to attain the maximum economy larger super-power stations may be built.

As far as can be seen, greater economy will be obtained by an increase in the size of units beyond the present limits. It may be anticipated that manufacturers will be asked to supply the largest machines they can build, consistent with a high standard of reliability and low maintenance costs.

In order to obtain the maximum economy an ample supply of cooling water is required for a power station, which means a greater concentration of large power stations near the estuaries of rivers. This location also has the advantage that the generating station is reasonably near the load centre and transmission losses are kept to a minimum. On the other hand, in view of the vulnerability of the power station from air attack and in order to obtain greater reliability of supply under normal conditions, some engineers favour decentralization and limitation of the ultimate capacity of power stations.

It is difficult to foresee what effect these considerations may have upon the size of generating units.

Within the next few years manufacturers will be prepared to build single units of 200 000 kW running at 1 500 r.p.m. if they are required; machines running at 3 000 r.p.m. will probably be limited to 50 000–80 000 kW.

Alternator Efficiency.

The gradual but steady increase in alternator efficiency obtained by improvements in design, manufacture, and quality of material, does not now leave much room for further gain, but the limit has not yet been reached.

An appreciable reduction in loss is obtained by the use of hydrogen in place of air for cooling, but its adoption entails additional cost and complication in construction and operation. Nevertheless, the gain in efficiency to be obtained may in time encourage its use.

The use of liquids for cooling has been successfully adopted for both alternator stators and rotors in the past, but without any greater economy of design, for which reason they have been abandoned.

Progress Made.

Apart from the conception of the concentric-conductor high-voltage alternator and its introduction into commercial service in 1928, there have been no outstanding developments in alternator construction since the change from salient poles to cylindrical rotors. Yet the progress made in recent years has not been inconsiderable. The effect of improvement in materials and details of design, construction, and manufacture, is strikingly illustrated by the reduction made in the weight of alternators during the past few years. The weight of a 30 000-kW 3 000-r.p.m. alternator built in 1937 is 30 % less than that of a similar machine constructed in 1931.

The success of 36-kV high-voltage concentric-conductor alternators indicates that even higher generating voltages may be practicable. There would be considerable advantage in direct generation at 66 kV and higher voltages. The use of hydrogen under a pressure of several atmospheres in a closed ventilation system has been suggested. The increased electric strength of this cooling medium would be of considerable value for high-voltage machines. The advantages of the high-voltage alternator and of hydrogen cooling may thus be combined in the future.

FUTURE OF GENERATION

Having reviewed the development which has taken place since the inception of the electromagnetic induction machine, the conclusion seems to be that, although the accomplishment has been great, it has been limited to only one section of the field. Ought we not to be turning our attention to other ways of utilizing the natural sources of energy?

The world possesses a large supply of coal and it appears likely to be the chief source of electrical energy for many years to come. Nevertheless, the greatest handicap to high fuel economy is the heat engine, which is limited by natural laws to a relatively poor performance.

There is a vast amount of potential water power in the world, and waterwheel alternators will be used to a large extent in the future in countries where the load centre is within reasonable distance of the hydro-electric station. The economical range of transmission even at 500 000 volts is at present limited to a few hundred miles. While there has been a greater development of water power in recent years, the amount produced is small compared with that obtained from coal.

The modern electrical power station using steam turbines is the most economical means of converting the stored energy of coal into electrical energy, and yet the overall efficiency is only of the order of 30 %.

Fifty years of development have been needed to reach this efficiency and it now appears to be approaching saturation level. It is unlikely that any appreciable improvements will be made unless metallurgists can produce metals to withstand a reasonable stress at much higher temperatures

The possibility of using other means than the steam turbine for converting the chemical energy in coal into electrical energy have often been discussed. Many methods have been considered, and the most hopeful appears to be the use of coal or coal gas as an active material in a primary cell.

The efficiency of an ordinary primary battery is high, but it has the disadvantage of being bulky and the active materials are expensive. A fuel cell would be constructed on different lines. The active material in the form of coal or coal-gas would probably be stored outside the cell and fed in as required.

An efficiency of 50 % has been obtained from experimental cells of this type, but they have not been made in a practical form. Generators of this kind installed in this country would probably be placed near coal mines, and their operation made entirely automatic. The cells would generate a direct current and it would be necessary at some stage in the transmission system to convert from direct current to alternating current. Rectifiers would be required at some point in order to retain the advantage of a.c. distribution, and the success of the system would be dependent upon an economical and suitable rectifier being available.

It may be of advantage while discussing the fuel cell to consider another possibility of the future. A wish has often been expressed for an efficient form of storage battery, low in cost and capable of containing a large amount of energy. There is no doubt that a battery of this description would greatly benefit many branches of the electrical industry.

A battery of the conventional type is bulky, heavy, and costly, in relation to the amount of energy stored. A large cell may be charged with less than 50 watt-hours per pound of material, which is equivalent to about 170 B.Th.U. A cell capable of giving 1 kW for a period of 24 hours on a storage and discharge cycle would weigh 480 lb. The cost of such a unit, including ground, buildings, conductors, switchgear, and other accessories, would be high compared with the cost of a complete generating station of equivalent output.

Even if it were practicable it would be undesirable to attempt to increase the charge in a storage battery of normal design. If it were found possible to store 1 000 B.Th.U. per pound of cell material, the stored energy would approach that of a high explosive. Nitroglycerine contains about 3 000 B.Th.U. and trinitrotoluene only 1 400 B.Th.U. per lb. In comparison, 1 lb. of coal in combination with the correct weight of oxygen, available in the atmosphere, may give 14 000 B.Th.U.

The only method of attaining this figure with a storage battery appears to be to use a fuel or a gas cell. The active material for the cell, which again would be stored externally, would be formed electrolytically during off-peak loads of the power stations.

Storage of this kind would lose much of its value where the source of power is coal, as it would be more economical to use the latter direct. A fuel cell consuming coal could also be used for transport vehicles, provided that the efficiency was sufficiently high to enable it to compete with the internal-combustion engine.

Storage of energy in this manner would be of special value to countries possessing an abundant source of hydro-electric energy.

It may require some time to develop a fuel cell of the required efficiency and utility, and it is probable that generating stations using coal-fired boilers, steam turbines, and turbo-type alternators, will continue in their present form for some years to come.

CONCLUSIONS

The engineer of to-day may feel reasonably and justifiably satisfied with the present state of development of electrical engineering.

It is of interest to read the views of a pioneer written nearly 60 years ago. In 1879, before the days of the first electrical supply system, W. H. Preece wrote—" The applications of electricity have a decidedly civilizing influence and the tendency of all progress is to subdue this subtle agency more and more to be the helpmate of man. It has been utilized for domestic and commercial purposes. It has brought the whole world into one fold. It has annihilated space. It has turned night into day. It has rendered time uniform and exact, and it has enabled our geographers and astronomers to perfect the measurements of the dimensions of the earth. Thus it has become a great economizer of time, and a great regulator of the disposition of our movements, and, therefore, of our lives."

The first portion of this statement has been amply justified; the claims made in the second part, comprehensive as they were, have been far surpassed.

Progress in the future is largely dependent upon research work by manufacturers and other organizations.

Facilities for research multiply day by day, while the knowledge which is being gathered in all fields of engineering and physics is expanding at a greater rate than it can be absorbed.

It is to be anticipated that considerable progress will be made in details of the present system of generating electrical energy, and that its cost will thereby be reduced. The present system is developing on standardized lines and there appears to be little prospect of any immediate major change.

It is important that research should not be confined to details and that new and broad lines of development should be covered.

Although this policy involves the expenditure of large sums of money for which there is no immediate return, it has been unhesitatingly adopted by the leading manufacturers of electrical plant.

The world's store of coal is ample at the present time and it has been computed that it will last for a few hundreds of years. In the course of time it may become more costly to mine and it will eventually become scarce. The efficiency of electrical generating plant will then be of first importance.

The possibility of finding new and more economical methods of generating electricity from coal has been mentioned. A large increase in the cost of coal would make water power more attractive and perhaps bring tidal power within economic range. The potential water power in this country is small, and the possibility of developing tidal power probably holds the most interest for future engineers.

In his imaginative essay on " The Last Judgment," Professor J. B. S. Haldane pictures the human race some million years hence utilizing tidal power to such a degree that they accelerate the end of the world. Their descendants on the planet Venus criticize them for not looking forward more than a million years.

The engineer of to-day looks ahead little more than a hundred years except as an idle speculation: yet it is necessary to take a much longer view if the present rate of progress is to be maintained.

IRISH CENTRE: CHAIRMAN'S ADDRESS

By Lieut.-Col. K. E. EDGEWORTH, D.S.O., M.C., Member.

"THE USE AND MANUFACTURE OF PEAT FUEL"

(Abstract *of Address delivered at* Dublin, 28*th October*, 1937.)

ECONOMIC ASPECTS

Let me begin my Address by saying something of the economic aspects of this problem, so that we may view the whole business against the appropriate background.

Modern industrial conditions tend to cause a drift of population from the countryside and from the smaller towns into dense industrial districts such as that centred about London. Also small countries are faced with the difficulty that imports must be paid for by exports, and that they are apt to develop an adverse balance of trade.

The generally accepted expedient, which is adopted in order to correct these effects, is to foster the creation of local industries behind a tariff wall, but the difficulty then arises that prices are raised and the standard of living declines. We are in fact on the horns of a dilemma: if nothing is done, the population drifts away for lack of employment, and if local industries are created behind a tariff wall the population is driven away by the high cost of living. From this dilemma there is only one means of escape—the local industries must be operated on an economic basis, that is to say they must be operated, within a reasonable period of time, at a degree of efficiency which compares favourably with that prevailing elsewhere. In the last resort the solution to the emigration problem rests with the engineer and the technician. Moreover, the number of industries which we can reasonably hope to establish on an economic basis is strictly limited, and in many cases the industries themselves are not of sufficient size to be of serious economic importance.

At the present time the Irish Free State imports about 2½ million tons of coal per annum, of a value of about £3 000 000. The purposes for which this fuel is used are approximately as follows: railways, 326 000 tons; gas, 280 000 tons; electricity, 33 000 tons; industry, 425 000 tons; other purposes, 1 556 000 tons; total, 2 620 000 tons.

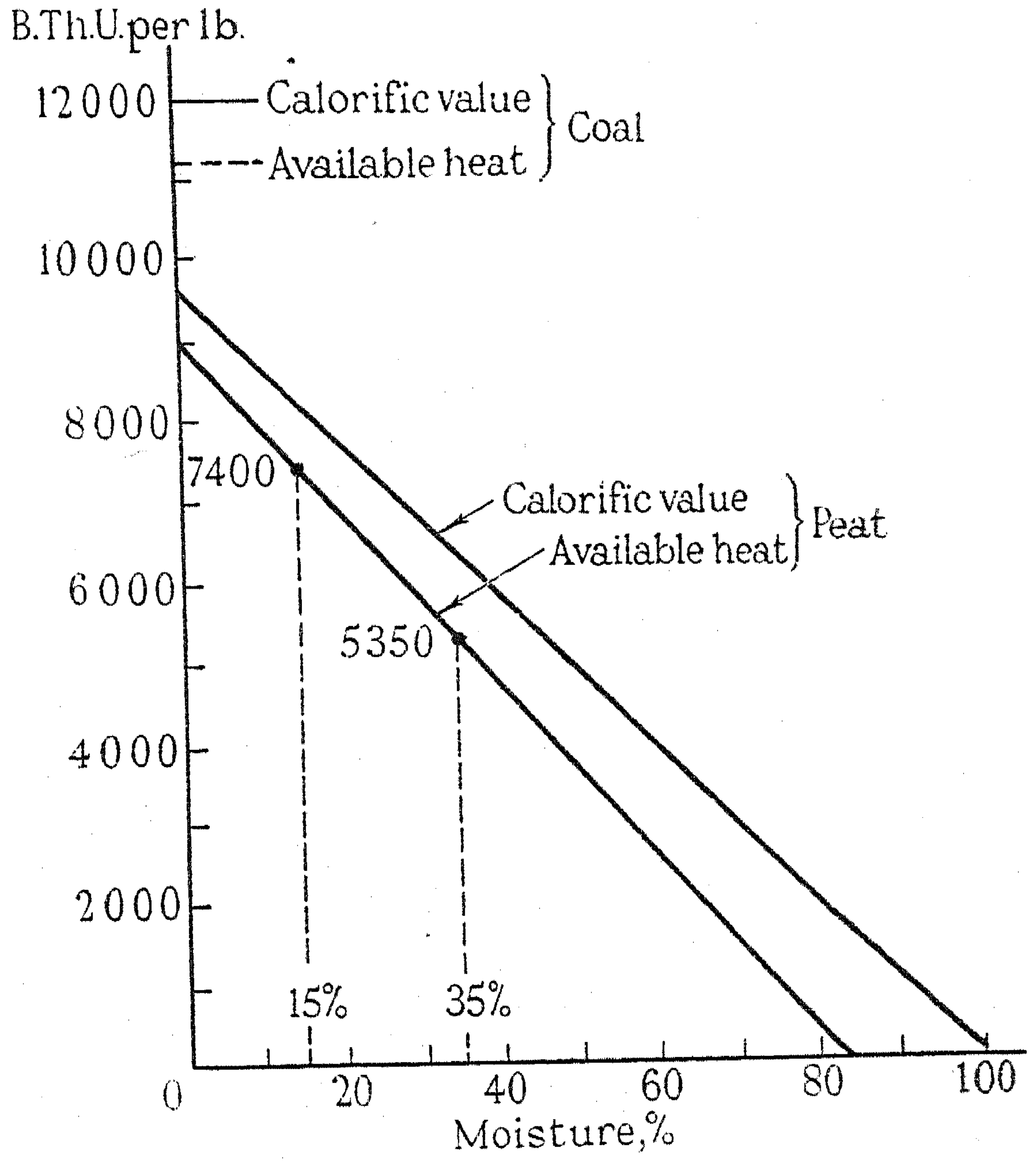
If the whole, or even an important fraction of these fuel requirements could be met by local production, the economic position of the country would be materially strengthened.

PROPERTIES OF PEAT FUEL

Compared with its chief rival—coal—the advantages of peat fuel are: (i) It does not melt when heated, as coal does; it can therefore be used in cases in which coke and anthracite are used at present. (ii) It keeps alight well —better than most other fuels. (iii) It is practically smokeless, and smokeless fuels are more efficient in use and command a higher price.

The disadvantages of peat fuel are: (i) Its calorific value is low; for a given quantity of heat produced, the cost of labour and transport are increased. (ii) Peat is bulky; for equal calorific value machine peat is 4 times as bulky as coal, and hand-cut peat 5 or 6 times. This involves larger apparatus, and increases the cost of transport. (iii) Peat is often friable. (iv) The proportion of moisture is high and may amount to 45 %; this means less heat available for heating, and slower combustion.

The extent to which peat fuel actually suffers from these various disadvantages depends on the method of manufacture. Machine peat is superior to hand-cut peat; It is denser, less friable, and contains less moisture. At the same time the supply of air-dried peat is uncertain, as it is dependent, to some extent, on the weather.



Calorific value and available heat, for coal and peat.

Note.—The available heat in peat containing 15% and 35% moisture is roughly equivalent to two-thirds and one-half respectively of the available heat in coal.

THE VALUE OF PEAT FUEL

The available heat, i.e. the calorific value less the heat required to convert the total moisture into steam, is given in the Figure, both for coal having a calorific value of 12 000 B.Th.U. per lb. and for peat containing various proportions of moisture.

Taking coal at 42s. per ton in Dublin and 52s. in the country, the comparative value of peat is:—

Coal	42s.–52s.
Peat, 15 % moisture ..	28s.–35s.
Peat, 35 % moisture ..	20s.–25s.

It is possible, however, that peat with 35 % moisture, which is difficult to burn, is worth rather less, while peat with 15 % moisture, which is a good smokeless fuel, is worth somewhat more.

The cost of coal at the docks is 23s. per ton, so that the cost of transport, storage, and distribution, in Dublin is 19s. per ton. There is no *prima facie* reason why peat should be cheaper to distribute than coal, and the problems of cheap transport and cheap distribution are just as important as the problem of cheap manufacture.

COMBUSTION PROBLEMS

In order that combustion shall be complete, it is necessary to admit a certain amount of air above the fuel bed. On the other hand, if too much additional air is admitted, the temperature of the fire is lowered, efficiency suffers, and the rate of combustion is retarded.

In large power stations the supply of additional air can be adjusted, but in smaller apparatus the amount of such air depends on the design of the apparatus itself.

Bituminous coal contains a certain proportion of volatile material which is driven off fairly rapidly whenever a fresh charge of fuel is placed on the fire; if these ingredients are not burnt they clog the flues in the form of soot and pollute the atmosphere in the form of smoke. It is necessary to arrange that a coal fire shall be supplied with sufficient additional air to ensure reasonably complete combustion during those periods in which the production of smoke is a maximum, with the result that there is an excess of air at all other times.

Peat, on the other hand, is practically smokeless, and there is no need to provide a large excess of air in order to ensure satisfactory combustion. At the same time the available heat in the peat is low, more especially if it contains much moisture, and the temperature of the fire, even under favourable conditions, is no higher than it should be. If any large excess of air is admitted, therefore, the temperature of the fire is lowered, the efficiency is reduced, and the rate of combustion falls off. If peat-burning apparatus is to work properly, the amount of additional air admitted to the fire must be strictly limited.

For these reasons, apparatus designed to burn coal needs a liberal provision for additional air and is unsuitable for burning peat, and apparatus designed for peat provides too little extra air and is unsuitable for burning coal. In the former case the peat fire will burn badly and the efficiency will be low. In the latter case the coal fire will produce a lot of smoke and the flues will become choked with soot.

Again, large furnaces and producers can be designed to burn peat containing up to 50 % moisture, but in small domestic appliances, such as stoves and cooking ranges, the effective limit is about 30 %. Beyond this limit combustion is possible but it cannot be regarded as entirely satisfactory. Nor can it be said that 30 % moisture should mark the limit of our endeavours; a fuel containing 10 % or 15 % moisture would be very much better.

Peat-burning Appliances

The progress which has been made in designing apparatus suitable for burning peat may be summarized as follows:—

(i) For large power plant, suitable furnaces can be designed. The only real trouble is that the apparatus must be larger on account of the greater bulk and lower calorific value of the fuel.

(ii) Small power boilers for heating and industrial purposes can be adapted to burn peat without much difficulty, but the peat must be reasonably dry. A Lancashire boiler using balanced draught has been working successfully on peat fuel at Mullingar.

(iii) The design of domestic appliances, particularly a cooking range and stove, have been under investigation by Prof. J. Taylor, working under the auspices of the Industrial Research Council. The problem to be solved may be subdivided as follows: (*a*) The design of appliances which will burn peat efficiently. (*b*) The design of appliances which will burn either peat or coal as required. (*c*) The design of arrangements for altering existing appliances so as to make them suitable for burning peat.

The first of these problems was solved some little time ago, and samples of cooking ranges and stoves were exhibited at the Spring Show. I understand that the second has now been solved also. The third problem still remains to be investigated.

ELECTRIC POWER

The consumption of electric power in the Irish Free State has doubled in the last six years. It was over 280 million units for 1936–37 and it is increasing at the rate of 40 million units, or 14 %, per annum. It is evident that additional generating capacity will have to be provided in the not-very-distant future. At the present time electricity is generated mainly from water power, and to a lesser extent from steam power stations burning coal.

A system based mainly on water power is open to the objection that it is adversely affected by exceptionally dry seasons, and in fact the Shannon Scheme did find itself in serious difficulties on account of an exceptionally dry season very shortly after it came into existence. A system based mainly on air-dried peat would be open to a similar objection, but with the difference that it would be adversely affected, not by very dry years but by very wet years.

The two systems are in fact complementary. If peat fuel could be produced at an economic price, the ideal system for this country would seem to be one based more or less equally on water power and peat fuel, and it is natural to suggest that expansion in the immediate future should be provided by power stations using peat fuel, rather than by further developments on the Shannon.

Accepting this proposition, at least for the sake of argument, certain technical problems present themselves for solution.

The Irish Peat Inquiry Committee of 1921 recommended the erection of a power station operated with gas engines. Thirty years ago there were many engineers who believed, firstly that the power stations of the future would be operated by gas producers and gas engines, and secondly that they would be located near the collieries. As matters have turned out, both these predictions have been falsified; the power stations which have recently been erected in Great Britain are not operated by gas producers and gas engines and are not situated near the collieries.

As regards the first of these points, the arguments in favour of gas producers and gas engines were: (i) Higher thermal efficiency. (ii) The production of sulphate of ammonia as a by-product. (iii) The production of tar as a by-product.

In actual fact these advantages have turned out to be less important than was anticipated; the steam turbine now approaches the gas engine in efficiency, sulphate of ammonia can be produced more readily by other means, and the tar from producers is of poor quality and not of much value. The initial and operating costs of the producer-gas-engine combination are, however, both high, and the value of the by-products does not appear to be sufficient to compensate for these disadvantages.

As regards the best location for a power station, an ample supply of water is essential; and it is then a question of balancing the cost of transporting coal against the cost of transmitting electricity, bearing in mind that electricity is a product which benefits from mass production, since large power stations are more efficient than small ones. Hence a scheme for producing electricity at the colliery or bog must be debited, not only with the cost of transporting the electricity to the market, but also with the additional cost of producing the electricity in smaller and less efficient stations. In Great Britain considerations of this character seem to have turned the scales definitely in favour of large power stations situated near the centre of the market, and against the alternative policy of locating the power stations near the collieries.

The Irish problem is not necessarily identical, for the fuel is bulkier and more difficult to transport, but the course which development has actually taken in other countries cannot be lightly brushed aside. Perhaps the solution will be found in the erection of a large power station in the centre of a group of bogs rather than the erection of several small stations.

APPLICATIONS OF PEAT FUEL

The chief purposes for which peat fuel can be used may be summarized as follows:—

(i) For domestic purposes in ranges, stoves, etc., as already described. In point of volume this is probably the most important market.

(ii) For central heating. Apart from its greater bulk, peat is just as suitable for this purpose as coke or anthracite.

(iii) For industrial boilers.

(iv) For electric power.

(v) As a basis for the development of special electrochemical industries.

The last item has been included in the list in deference to the 1921 report of the Irish Peat Inquiry Committee, but the proposal does not appear to be sound. The essential problem is to produce a fuel which can be used as a substitute for coal.

As regards the use of peat in cooking ranges and stoves for domestic purposes generally, there is undoubtedly a large potential market, but if the fuel is to be accepted as satisfactory it should contain not more than 30 % moisture. Moreover, a fuel containing 15 % moisture is definitely superior to a fuel containing 30 %, and it would certainly be much more popular with consumers. On the other hand, peat containing 35 % or 40 % moisture can be used quite effectively in large furnaces. If peat containing 35 % moisture can be produced for 8s. or 10s. a ton, there are no technical reasons why the fuel should not be used for generating electric power.

Until the process of manufacture is so far improved that the moisture content in the fuel is never in excess of 30 %, the most hopeful field for the use of peat fuel would appear to be that of the generation of electricity.

Another very interesting question arises in this connection—Should the same bog be used for supplying peat for electric power and also for domestic purposes? Without passing final judgment, there seems to be a good deal to be said for the argument that all bogs within a reasonable distance of a new power station should be allotted exclusively for the generation of power, and that other bogs should be allotted to meet other requirements.

THE MANUFACTURE OF PEAT FUEL

Raw peat in an undrained bog contains up to 93 % moisture. By drainage the proportion of moisture can be reduced to 88 % or 90 %. If peat is to be used as a fuel the greater part of this moisture must be removed, and the removal of the superfluous moisture is the chief problem to be dealt with in the process of manufacture. Closely associated with the problem of removing the moisture is the problem of producing a fuel which is hard and dense and reasonably convenient for use and transport. The value of the final product depends very largely on the extent to which these objectives can be realized.

Hand-cut Peat

Hand-cut peat usually suffers, to a serious extent, from all the disadvantages already referred to; it is bulky and friable and may contain as much as 45 % moisture. Quite definitely a fuel containing such a high percentage of moisture is unsuitable for general use.

Machine Peat

A very important advance in connection with the manufacture of air-dried peat was the discovery that the rapidity of drying is increased, and the quality of the product is greatly improved, if the raw peat is passed through a macerator. In its original condition the raw peat is spongy and fibrous, and the partially dried peat is liable to re-absorb moisture; the macerated peat does not suffer from this defect to any serious extent, and rain falling on it runs off the surface, so that drying is resumed as soon as the rain is over.

The credit for developing a practicable process based on these principles should apparently be given to Von

Weber, who elaborated a system for producing machine peat at Staltach in Bavaria in 1858. Various forms of the process are being worked successfully on the Continent, but no attempt to introduce any such method into this country has hitherto been commercially successful.

Peat Works at Turraun

The peat industry at Turraun was originally started for the manufacture of peat-moss litter, and that part of the business is still in existence. Somewhat later, under the guidance of Sir John Griffith, the manufacture of peat fuel was developed. About 2 years ago the business was acquired by the Turf Development Board.

The process in use at Turraun may be outlined as follows:—

The bog is first drained, which reduces the moisture from, say, 93 % to about 90 %. At the same time a long deep drain is cut in the bog, and the upper surface of the bog is levelled. After 2 or 3 years, when these preparatory operations have had time to take effect, the main manufacturing operation is commenced.

A dredger running on rails cuts away the peat from the side of the drain and empties it into a macerator. The peat leaves the macerator in the form of blocks, which are delivered on to a conveyor. The conveyor, which is supported on rollers, extends across the surface of the bog at right angles to the working face, and the delivery of peat on to the conveyor is continued until the whole length of the conveyor is full. An arrangement then comes into operation which tips the blocks from the conveyor on to the bog. The dredger and conveyor then move forward a short distance, and the operation of filling the conveyor begins over again. The final effect of the process is to leave the surface of the bog, extending from the working face to a distance equal to the length of the conveyor, closely covered with blocks of macerated peat.

After a period of 3 or 4 weeks the peat blocks are sufficiently dry to be collected into small heaps, and after a further period of drying they are put into baskets and collected into ricks, the ricks being formed in a continuous line on the edge of the drying ground furthest from the working face. The peat remains in the ricks, where it undergoes some further drying, until it is required for use, and it is then removed from the bog by means of a light railway.

It will be noticed that the process of dredging takes the peat from the whole depth of the bog simultaneously, and that the final product is a mixture of all the different layers. A process which took the peat from the surface of the bog would yield a light fibrous form of peat at first, and the quality of the peat would then improve as the working surface got deeper.

The cost of production at Turraun was given by Sir John Griffith three years ago as 20s. per ton. Since that time the machinery has been improved, and it is believed that the present cost is about 15s. per ton. The actual operations have been seriously hindered by labour troubles, however, and the above figure is only an estimate and is not the result of actual working. Also the Turraun bog is ill adapted, in various ways, for exploitation by this particular process.

Peat Works at Clonsast

A bog at Clonsast near Portarlington is now being developed by the Turf Development Board, and it is hoped that production from this enterprise, which is to commence in about 2 years' time, will eventually reach about 100 000 tons per annum. It is believed that this bog and others in the neighbourhood are easier to drain, and are more suitable for manufacturing purposes, than the bog at Turraun.

In 1934 a delegation visited various peat works on the Continent. One of the places visited was Meppen in Northern Germany, where a company was found to be operating successfully under conditions very similar to those prevailing in this country. The process is fundamentally the same as the one which is now in use at Turraun, but the machinery employed has been much improved and the cost of production has been considerably reduced. Taking into consideration the better character of the bog, the advantages to be gained by the use of improved machinery, and the reduction in overhead costs due to working on a large scale, it is estimated that at Clonsast it will be possible to produce peat fuel and deliver it at the end of the bog railway at a cost of 8s.–10s. per ton.

It may also be mentioned that the work at Clonsast has not been entirely free from labour troubles, and it would seem that this question of labour has not perhaps received the attention which it deserves. No enterprise can be expected to operate effectively unless it is worked by an efficient and contented labour force, and this is especially so when the workmen are scattered over a large area. Labour problems have been receiving increased attention in Great Britain in recent years, and most large firms have a special official to deal with such matters. This aspect of the peat-fuel industry appears to be deserving of special attention, for much of the work is done under difficult and arduous conditions.

The fuel which is finally produced by the process in question may contain as much as 35 % moisture. This is a great improvement on hand-cut peat, but is definitely less than the 30 % which should I think be regarded as a maximum. The fact that the consumer may sometimes get peat containing only 25 % moisture is not helpful. What is needed is a uniform and reliable product.

In my judgment a fuel containing 35 % moisture is unlikely to give satisfaction to the consumer, and the manufacturing problem cannot be regarded as solved until this result can be improved upon. It may be added that an attempt to force an unsatisfactory fuel on the consumer is likely to create a mass of prejudice which it may take years of effort to remove.

Peat Works at Lullymore

Another very interesting process is now in course of development at Lullymore in Kildare by the Peat Fuel Co., a private company which has been given a certain amount of Government assistance. The object of the process is to produce, not rough blocks containing 35 % moisture, but briquettes containing about 10 %.

The process is based on a system which is now being successfully exploited at Kaas in Denmark. It consists of four stages:—

(i) Air drying on the bog to reduce the moisture to 50 %–55 %.

(ii) Grinding the peat, and passing it through screens to remove fibre and other impurities. The rejected residue, amounting to 10 % or 15 %, is used for firing the boilers.

(iii) Drying the material passed by the screens by heat, so as to reduce the moisture to about 10 %.

(iv) Pressing the dry peat powder into briquettes.

The final product has a moisture content of 10 % only, and must be valued accordingly. Owing to differences between the conditions prevailing in this country and in Denmark, the machines in use in the latter country have not proved entirely satisfactory here, and it has been necessary to modify them to meet the local conditions. As yet it is too early to say whether the process can be developed successfully in this country, and the cost of the resulting fuel is also a matter of conjecture.

Possible improvements.

The methods of air-drying peat which I have described require for their successful development bogs of suitable type and of considerable size. Time is lost in moving the heavy dredger from one working face to another, and a clear run of 4 or 5 miles is desirable. There is clearly a need for smaller and lighter machines capable of exploiting the smaller and less regular bogs. A machine for collecting the dry blocks and piling them in small heaps, an operation which is now performed by hand, would also be a considerable improvement.

I mention these problems to show that there is no reason to suppose that the design of peat-winning machinery has yet reached finality.

Wet carbonizing and the Madruck process.

These two processes aim at reducing the moisture content to about 50 % in a filter press. They have not so far been commercially successful.

An interesting fact about wet carbonizing is that the amount lost in the venture was over £1 million, and one cannot help feeling that it ought to have been possible to create a successful process, or alternatively to prove that the process was unworkable, at a less cost than this.

MARKETING AND DISTRIBUTION

Theoretically the marketing problem can be settled by the simple expedient of passing a law that only peat fuel shall be supplied to everyone living within a certain area, but such a proceeding involves the maximum of inconvenience to individuals. I shall assume, at least for the sake of argument, that the correct policy is the one which will create the desired market for peat fuel with the minimum of inconvenience to the individual consumer. Such a policy has at least the merit that the scheme may be relied on to invoke a certain amount of patriotic enthusiasm, whereas attempts to use force only provoke passive resistance.

On this basis, the following difficulties have to be considered:—

(i) The supply is necessarily dependent, to some extent, on the seasons.

(ii) At present most of the existing apparatus for burning coal is unsuitable for burning peat, and the alteration or replacement of existing apparatus will take time.

(iii) Owing to the low intrinsic value of peat fuel, the costs of transport and distribution are of special importance.

If the new apparatus for burning peat were unsuitable for coal, the problem of equalizing supply and demand would be a very difficult one. The prospect that all new apparatus will be capable of burning either peat or coal at will removes this difficulty and would appear to be a development of far-reaching importance.

As regards distribution, a fuel which has only half the value of coal cannot stand distribution costs of 20s. per ton, and the question of lowering distribution costs is very important. It is no good assuming that a transfer of the distribution business from the present distributors to the Government would lead to serious economies; what seems to be needed is not so much a change of master as a change of method.

Coal is brought to this country in ships, and a ship must be unloaded as soon as it arrives. It follows inevitably that the coal cannot be taken direct to the consumer from the ship; it must first be taken to store, and it must then be distributed from the store to the consumer.

With peat the problem is different. The peat is already stored on the bog in a perfectly convenient and accessible manner, and there does not appear to be any justification for forming an intermediate storage depot of any kind. The proper procedure would seem to be to keep the peat on the bog until it is wanted, and then transport it as directly as possible to the consumer. That is to say, the peat would remain in the ricks until it was required, it would be brought by light railway to a convenient transfer station where it would be transferred to lorries, and it would be taken by these lorries to the actual consumer.

Such a method of distribution would involve careful and thorough organization in order to ensure that the needs of every customer would be met without undue delay, but the problem does not appear to be insoluble. Assuming the scheme to be working properly, the cost of distribution for a radius of 20 or 30 miles from the bog ought not to exceed 10s.–15s. a ton, so that the cost of peat (35 % moisture) to the consumer would be 20s.–25s. per ton, which is an economic price.

The question of delivering peat at greater distances from the bog raises problems of transport which have not yet been worked out.

Transport

Within a radius of 20 or 30 miles from the bog, it seems clear that peat fuel can conveniently be distributed by lorries working directly between the bog and the consumer. For greater distances it is probably necessary to introduce some other form of transport, and various problems present themselves for solution. Firstly, there is the question of suitable vehicles, for vehicles designed for carrying coal may not be economical for carrying peat. Secondly, there is the question of transferring the fuel from one type of transport to another—from the bog railway to the main railway or the canal, and from the main railway or canal to lorries or carts for final distribution. These problems have been discussed, but, so far as I am aware, no great amount of progress has been made towards their solution.

RESEARCH

Industrial progress depends on research, and there appears to be a vast field for research with a view to increasing the efficiency of local industries or alternatively of discarding them as unworkable. In the case of peat fuel the field can be subdivided into different parts dealing with use, manufacture, transport, and so on. In regard to use, the problem of devising means for converting existing domestic appliances so as to make them suitable for using peat fuel is perhaps the most urgent.

The existing organization is headed by the Industrial Research Council, and the principle is that money voted for research is allotted by the Council for particular purposes. The actual investigations are usually carried out at the universities. The method has many obvious advantages, and has undoubtedly yielded valuable results, but the total output which can be secured by this means is limited. There is reason to believe that the limit of output has in fact been reached, and that if the output is to be increased the existing organization will have to be augmented. In Great Britain there is a Fuel Research Station, which employs a permanent technical staff, and if the output of research work is to be increased the work now being carried out in the universities should be augmented by the allotment of more money and by the creation of a permanent research department with its own technical staff.

In regard to methods of manufacture, several problems have already been mentioned, but perhaps the most urgent is the problem of reducing the moisture content of the peat which is manufactured by the process now in use at Turraun, and which is to be used for the new enterprise at Clonsast. If a suitable process could be worked out, the cost might amount to 3s. per ton for additional material, 1s. for fuel for drying, 2s. for labour and other charges; total 6s. per ton. The resultant fuel containing only 15 % moisture would be worth 8s.–10s. per ton more than the original fuel containing 35 %, so that the process would be well worth while.

The efficient production and use of peat fuel are matters of very great national importance, and a liberal endowment of research into all aspects of the problem is the surest method of arriving at a satisfactory solution. When it is remembered that about £3 millions is spent annually in the purchase of coal, it is clear that the expenditure of a considerable sum of money on research would be more than justified.

There is also another important point. The development of any new process must go through certain well-recognized stages. Firstly, small-scale experiments or research. Secondly, large-scale experiments, which almost invariably disclose a number of difficulties which have not cropped up in the earlier experiments. Finally, commercial exploitation. Experience shows only too clearly that any attempt to rush the earlier stages leads invariably to failure and disappointment. The case of wet carbonizing already mentioned is very much to the point.

I should also like to refer to another aspect of the matter which seems to be worthy of attention. It must be remembered that the country is at present quite unable to absorb the full output of graduates from the universities, so that a large number of young people representing the best-educated and most intelligent part of the community are leaving the country to seek employment elsewhere. It is not sound practice to solve all our technical problems entirely by calling in expert advice from abroad. While not suggesting that foreign developments should be ignored, it would certainly be better in many ways if we made greater efforts to solve these technical problems for ourselves.

Again, it cannot be suggested that Irish engineers are not as fully qualified to tackle these problems as those of any other nationality. Reference has already been made in the course of this Address to the way in which the production of electric power has been revolutionized by the development of the steam turbine, and it is well to remind ourselves that Sir Charles Parsons, to whose skill and perseverance the development of the steam turbine was due, was a member of a well-known Irish family.

The importance of keeping our young engineers and technicians at home and of giving them adequate facilities for improving the efficiency of our local industries can hardly be over-emphasized.

SUMMARY

The present position with regard to the development of peat fuel may perhaps be summarized as follows:—

The whole business, which embraces methods of use, methods of manufacture, marketing, and the organization of research, is still associated with a number of unsolved and partially solved problems for which solutions must be found before the industry can be firmly established on a satisfactory economic basis. The various difficulties, to some of which reference has been made in this Address, will be overcome if they are carefully studied and properly understood before active steps are taken to deal with them, and a liberal endowment of research is the only means by which progress can be assured.

At the same time, if the attack is pursued with sufficient determination and in the proper scientific spirit it does not seem to be too much to say that this great national problem appears to be within measurable distance of solution.

In conclusion I wish to acknowledge gratefully the help which I have received in the preparation of this Address, and particularly from the following:—

Mr. C. S. Andrews, Mr. T. McMahon, and Mr. E. V. Switzer, of the Turf Development Board; Mr. T. Biath and Mr. D. J. Purcell, of the Peat Fuel Co.; Prof. H. Kennedy; Prof. P. F. Purcell; Prof. J. Taylor; and the Electricity Supply Board.

EAST MIDLAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By D. H. PARRY, B.Sc., Associate Member.

"PROBLEMS OF POWER STATION DESIGN DURING THE NEXT DECADE"

(*Address delivered at* LOUGHBOROUGH, *5th October*, 1937.)

PAST METHODS OF POWER STATION DESIGN

For the benefit of those who are not in close touch with power-station practice I will review very briefly the broad principles of station design, and in the first place I must state that my remarks will deal only with steam-driven power stations, which in this country generate 96 % of the total number of units of electricity produced.

The size of a power station is determined by the maximum demand in kilowatts from the area it supplies. The location of a power station is determined by economic considerations at a point as near as possible to the centre of gravity of the load. It must also be (*a*) near a source of fuel, (*b*) near an abundant supply of water for cooling and feed-water purposes, and (*c*) on a site provided with rail and road access and suitable for the construction of the engineering works which make up a power station.

For several obvious reasons the complete power station is not built at once but is designed for easy extension. Boiler plant and turbine plant are divided into a number of units to facilitate overhaul and repair work and to maintain a reasonable thermal efficiency at different demands. The completed station would have usually 5 or 6 generating sets and 10 to 20 boilers, and, in estimating the maximum load to be safely carried, one generating set and two or more boilers would be regarded as out of commission.

The 1926 Electricity Act established the Central Electricity Board to co-ordinate electricity generation and inaugurated the linking-up of power stations by high-tension lines known as the Grid. Prior to this Act the size of plant was restricted by the magnitude of the supply undertaking, but now more latitude is possible and a more economic size of plant chosen. Stations in favourable positions for obtaining water and coal may be enlarged and more fully utilized.

The Central Electricity Board, in controlling the operation of stations to give maximum efficiency, have divided them into three classes:—

(A) Stations in continuous operation throughout the year.

(B) Two-shift stations normally giving no output at night or between Saturday afternoon and Monday morning.

(C) Two-shift stations normally generating during day and evening shifts on weekdays in winter and shut down during the summer.

In Central England there are approximately 5 "A" stations, 6 "B" stations, and 8 "C" stations; the "A" stations carry approximately 50 % of the maximum demand and generate 80 % of the units: the "B" stations carry 30 % of the maximum demand and generate 18 % of the units; while the "C" stations carry 20 % of the maximum demand and generate only 1 to 2 % of the units.

It is convenient to describe the stations of these three classes as base-load, day-load, and peak-load respectively, but it will be understood that the plant in "A" stations is not all of base-load character. The base load of the system is perhaps equal to 20 % of the maximum demand and 40 % of the output in units.

Since the grid has been in operation, a number of extensions have been made to stations in class "A," a few extensions to stations in class "B," but no extensions to stations in class "C." It is of interest to speculate whether this classification of stations is a permanent one, and whether future extensions of generating plant will follow previous practice.

No conclusion can be reached on this point without consideration of the possibilities of load development.

DEVELOPMENT OF LOAD

In an attempt to forecast the future development of electrical load I have studied the development of load in the area of Leicester electricity undertaking. Whilst this has been done for convenience, comparison of statistics with other undertakings show that it is reasonable to assume that its progress is typical of the majority of undertakings throughout the country.

During the last 10 years the number of units sold has increased approximately threefold and the maximum demand 2½ times.

Progress in sales to domestic consumers is the striking feature of the last few years, and the units sold under the domestic tariff now amount to 43 % of the total. For comparison, the units sold for power and factory lighting amount to 41 % of the total.

An examination of the potential sales to domestic consumers reveals that only a fraction of this business has been obtained, whereas factory electrification is nearly complete and future increases must be confined to natural expansion of business.

Curves have been prepared of the expansion of load, and from an examination of them it is reasonable to expect that the units sold in 10 years' time will again have increased threefold but that the proportion of domestic units will have increased to 70 % of the total.

If these estimates are realized generally throughout the country, the loading of generating stations will be dominated by the domestic load, and the incidence of this load will require careful study.

During the last 10 years the domestic load, by reason of diversity with other loads, has improved the general load factor, but in future years further increase of this load may have the opposite effect.

In the year 1936–37, the Leicester undertaking sold 136 million units with a maximum demand on the generating station of 55 000 kW. If in the year 1946–47 Leicester Corporation sells 400 million units, then, supposing that the load factor remains the same, we must provide for a maximum demand on the generating station of 160 000 kW.

INCIDENCE OF THE DOMESTIC LOAD

It is general experience that the bulk of domestic load may be expected from (*a*) cooking, (*b*) space heating, and (*c*) water heating. These services require many times the number of units consumed for domestic lighting and for such other services as vacuum cleaners, irons, washboilers, and so on.

The cooker load is responsible not only for a large consumption of units but also for imposing a sharp peak demand on the system at midday. It is the habit of most families to cook at midday and nearly at the same time, and the result is a peak load on the station amounting to 0·75 kW in mid-week and 1·75 kW on Sunday morning per cooker installed. These loads vary little in summer and winter, and probably differ little between one town and another throughout the country. In the use of electric fires and water heaters, habits are more diverse and peak loads not so well defined.

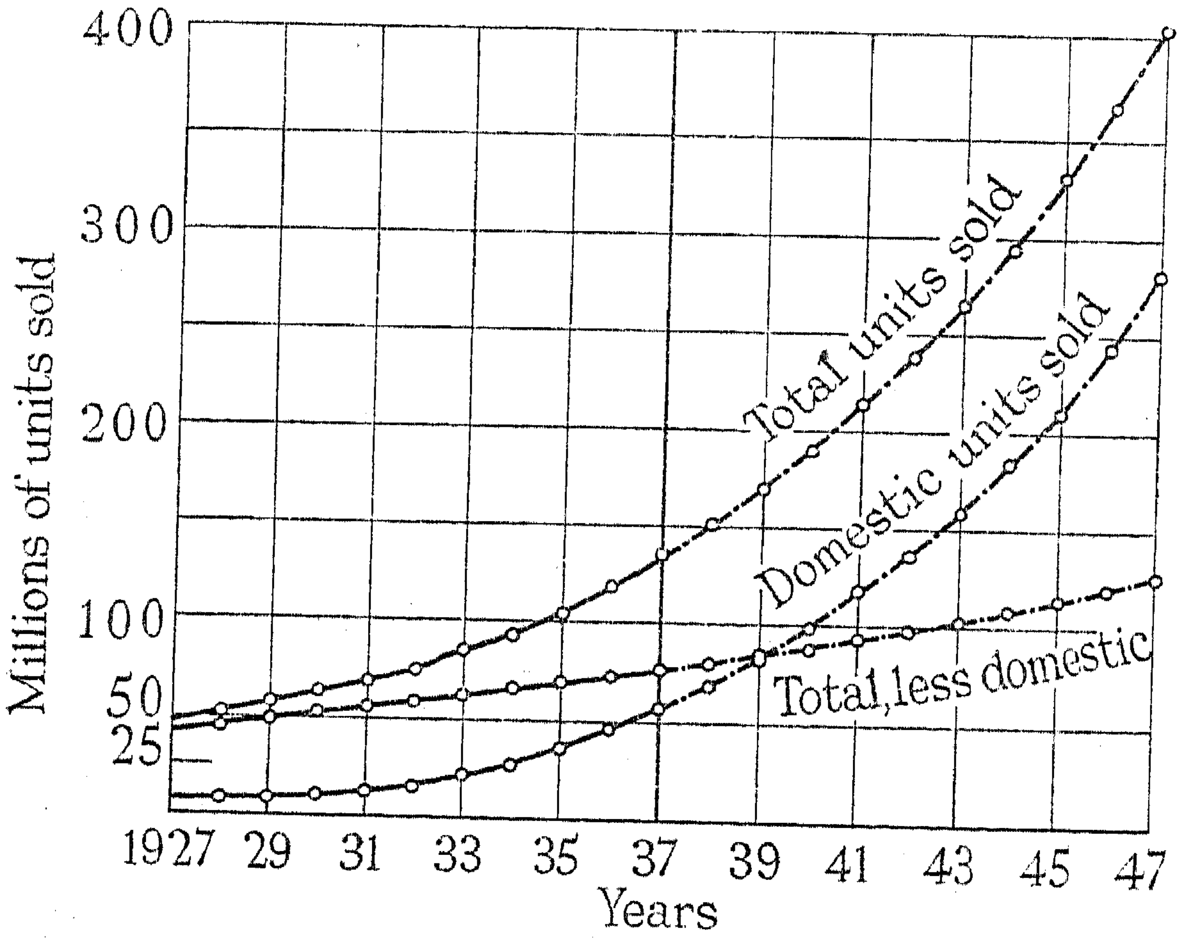


Fig. 1.—Curves to show the growth of load from 1927 to 1937. The curves are extrapolated to show probable growth from 1937 to 1947.

In Leicester, with nearly 20 000 cookers installed, the demand on the station is 15 000 kW during the week and 35 000 kW on Sunday. There is, however, a potential load of 100 000 cookers, and, whilst it may not appear probable that these will be installed during the next 10 years, the possibility must be examined. This number of cookers would produce a peak of 75 000 kW on weekdays, of which 30 000 kW would last only 1 hour. On Sundays the peak load would be 175 000 kW, of which 30 000 kW would last 2 hours.

A maximum demand of 160 000 kW has been estimated for the year 1946–47, but evidently when heating and other loads are added to the cooker peak this figure may be very considerably increased.

Water heating and space heating may offer some diversity with the cooker load, but present indications are that in 10 years' time the cooker peak will tower above the general level of electrical load.

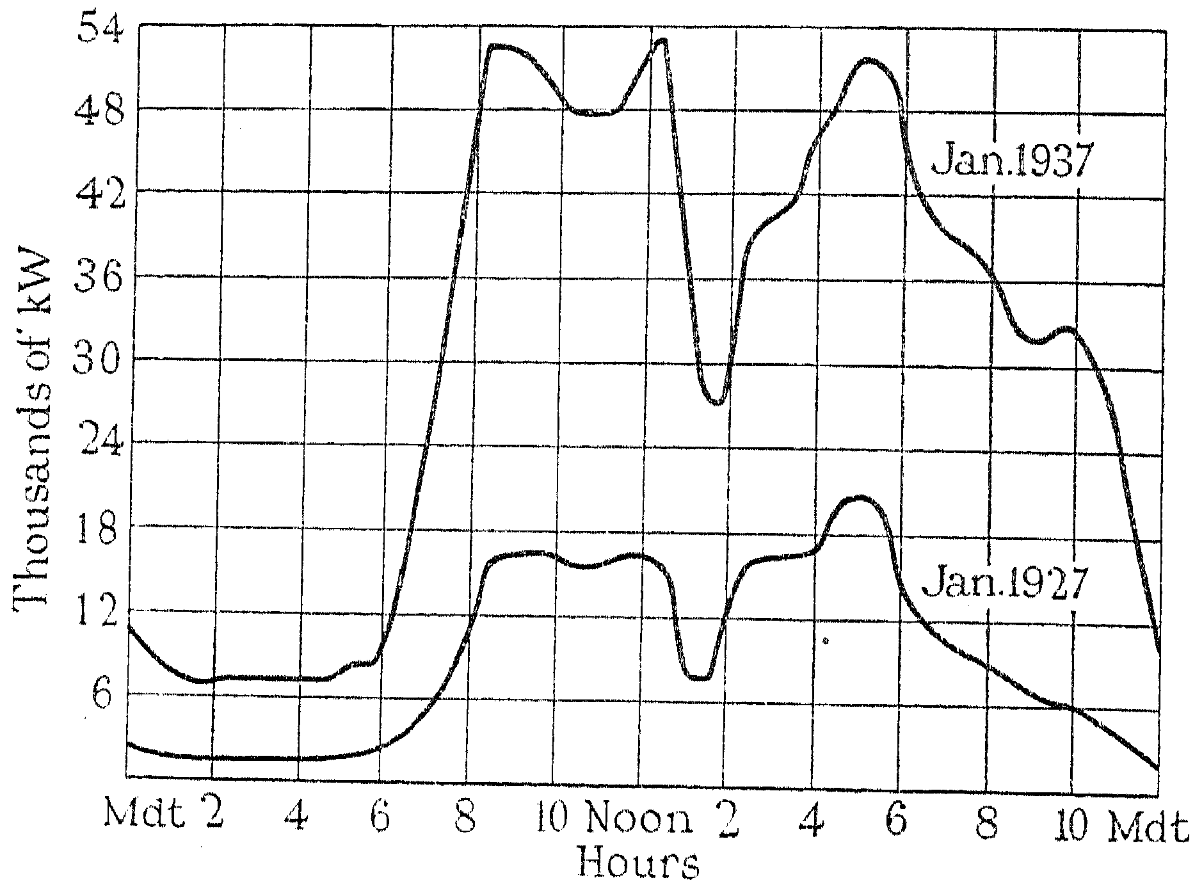


Fig. 2.—Load curves for typical winter weekdays in Leicester, 1927 and 1937.

Figs. 1–9 show load curves for Leicester on typical days in 1927 and 1937, and hypothetical load curves for similar days in 1947. A study of these curves reveals the onerous nature of the peak loads for which provision must be made in the power station of 1946–47.

The grid is at present making savings in fuel and plant by improving the plant load-factor in power stations, but this improvement can only be appreciable when load diversity exists between the towns linked up. I suspect that the diversity of cooker load at midday between towns is negligible, but in any case it appears neither sound economics nor good engineering to transfer such large peak loads of short duration over grid transmission lines.

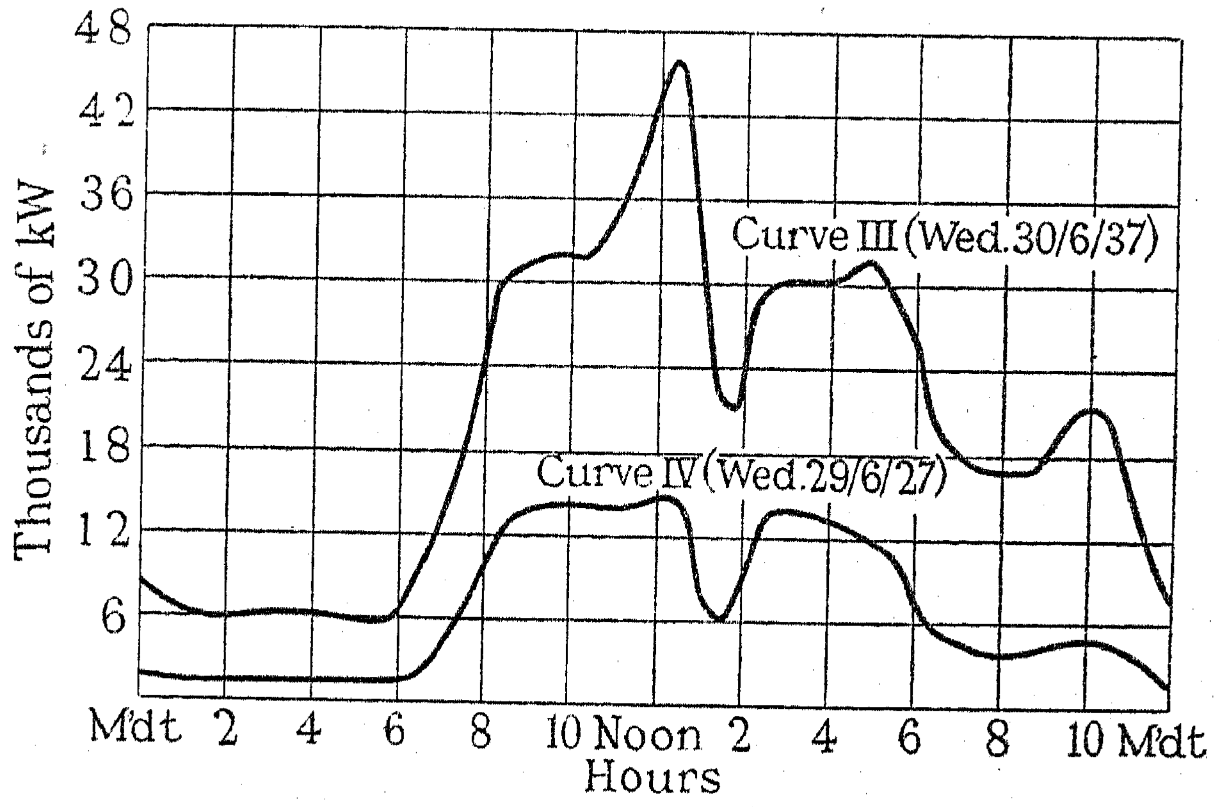


Fig. 3.—Load curves for typical summer weekdays in Leicester, 1927 and 1937.

I would suggest, therefore, that the chief problem in the design of power stations in 10 years' time will be to meet sharp peaks of short duration to provide for the cooker load.

PLANT OPERATION TO MEET LOAD

The capacity of a power station with turbo-generating plant is limited by the area of the inlet nozzles of the turbines. The efficiency of a turbine is at the highest when the inlet nozzles are passing the maximum quantity of steam. Once the nozzles are passing the maximum quantity of steam, any further load imposed on a turbine would cause it to slow down and ultimately to stop. The chief aim of efficient station operation is, therefore, to maintain the maximum load on a turbine without ever exceeding it, but as this is very difficult there must always be a margin to allow for unexpected contingencies.

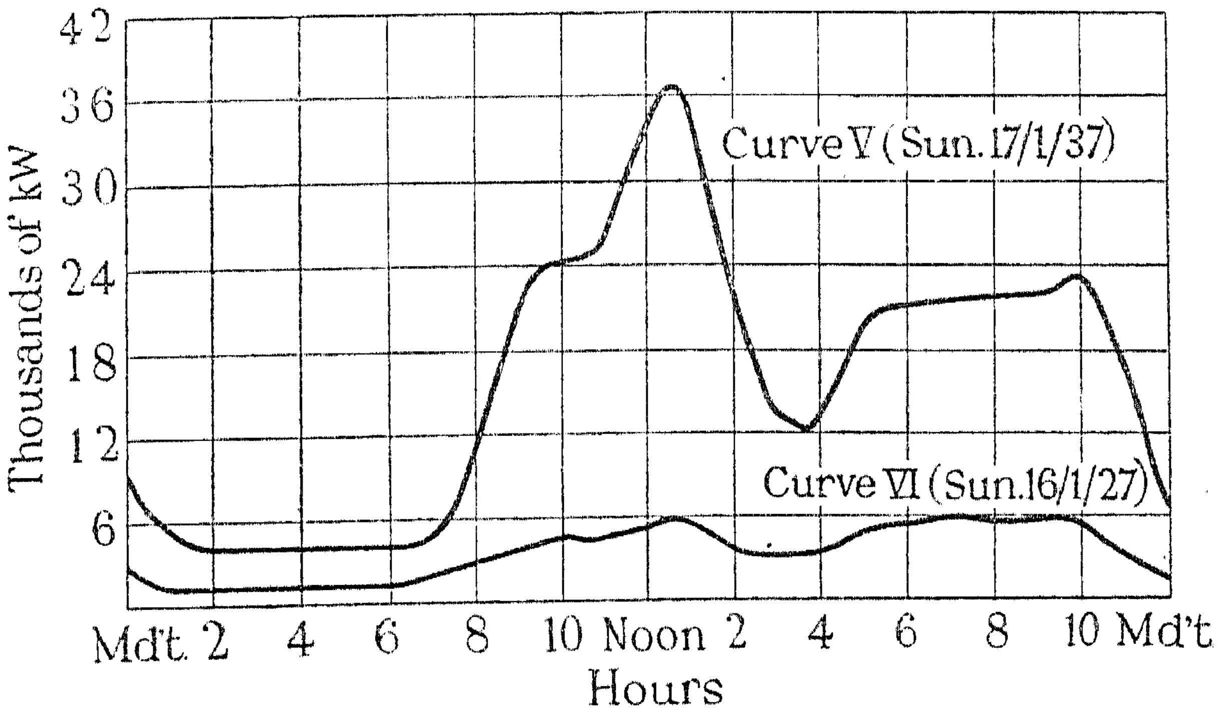


Fig. 4.—Load curves for typical winter Sunday in Leicester, 1927 and 1937.

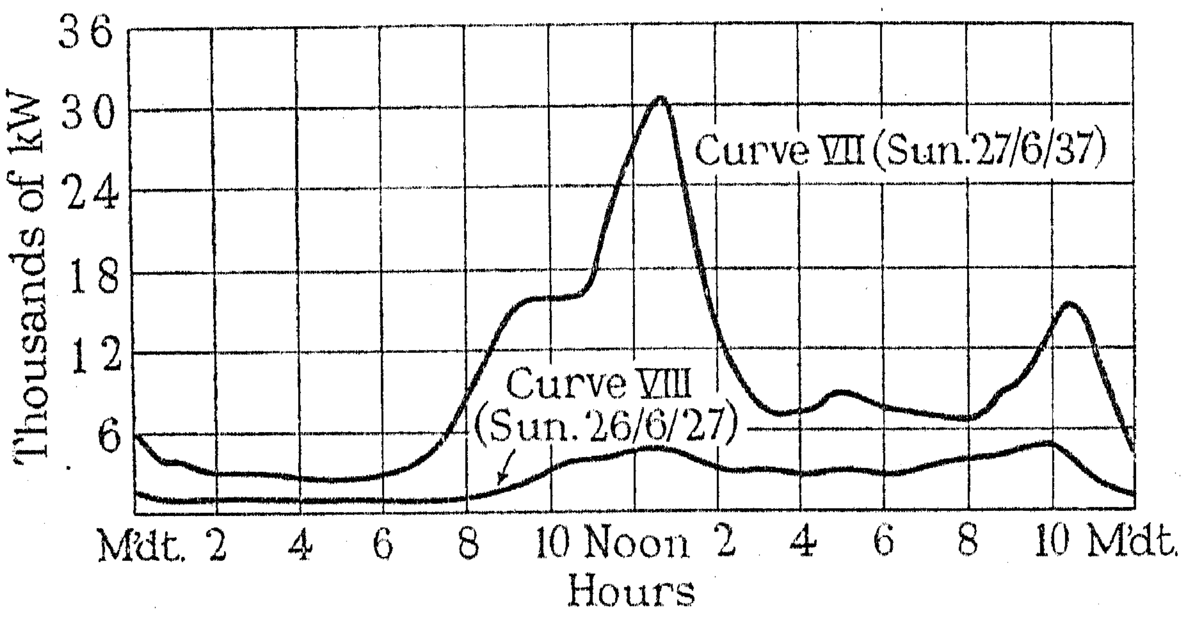


Fig. 5.—Load curves for typical summer Sunday in Leicester, 1927 and 1937.

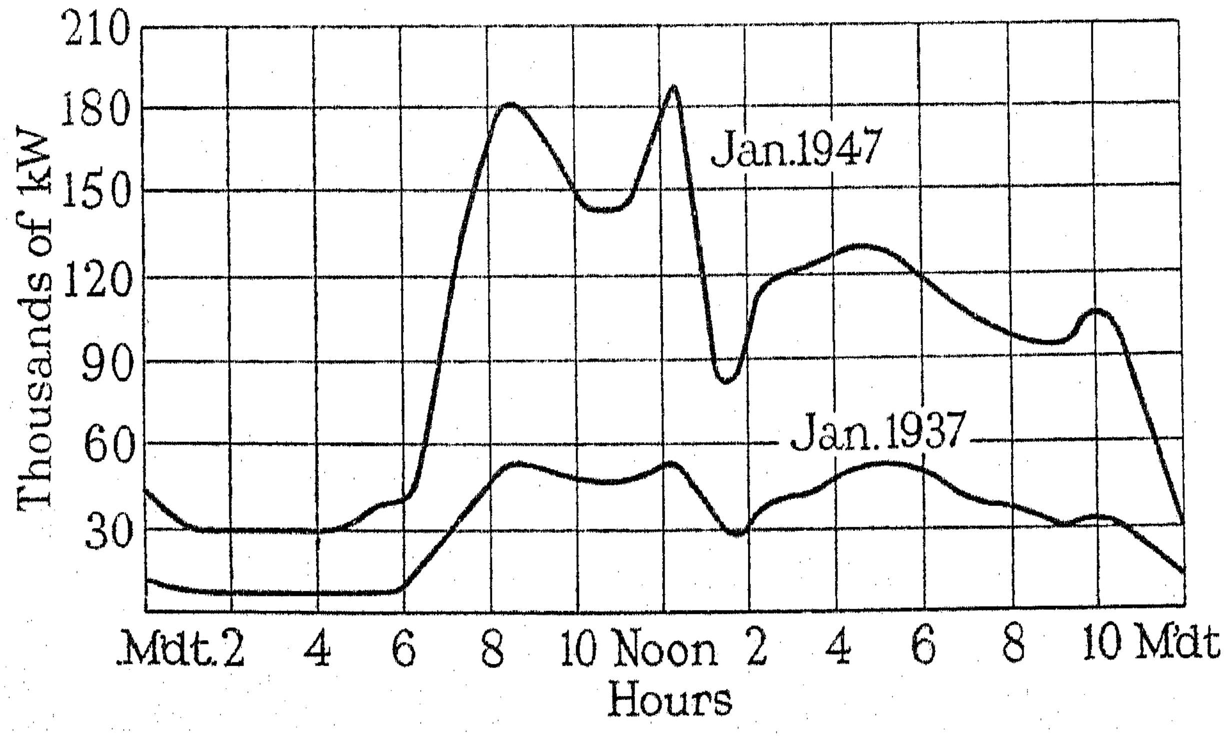


Fig. 6.—Load curve for winter weekday in 1937, and hypothetical load curve for similar day in 1947.

As may be seen from load charts, the range of loads on the power station is large, and if carried on one machine the average efficiency would be low. There would also be a considerable risk of the machine breaking down and not being available to carry any load. Efficiency can be increased and the risk of breakdown reduced by operating several machines in parallel at periods of heavy load, some machines being shut down at light load.

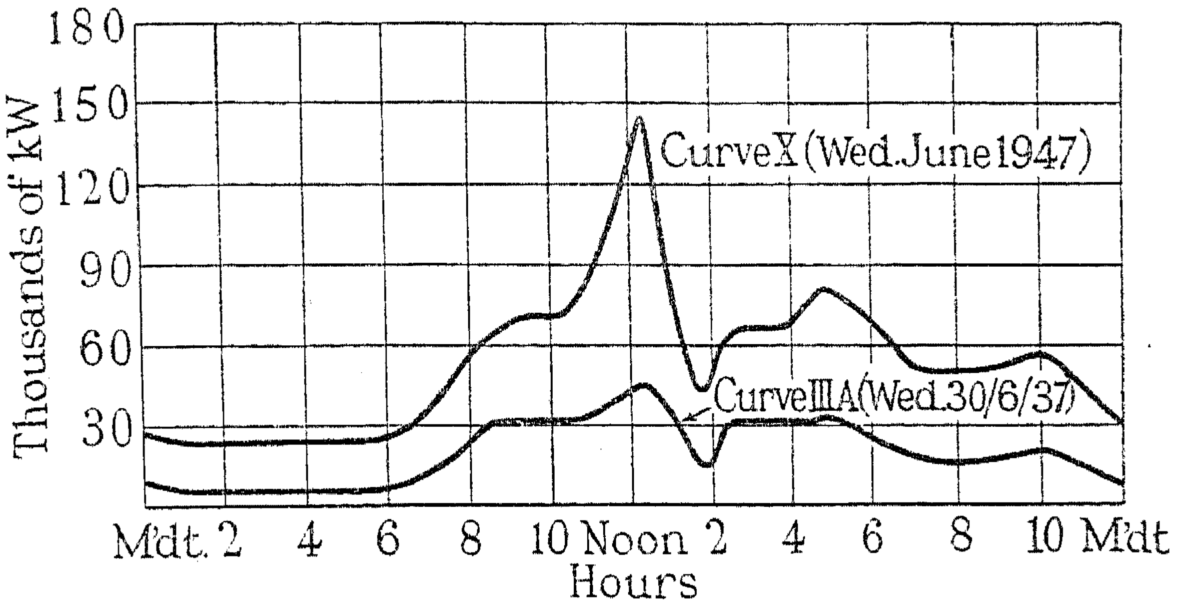


Fig. 7.—Load curve for summer weekday in 1937, and hypothetical load curve for similar day in 1947.

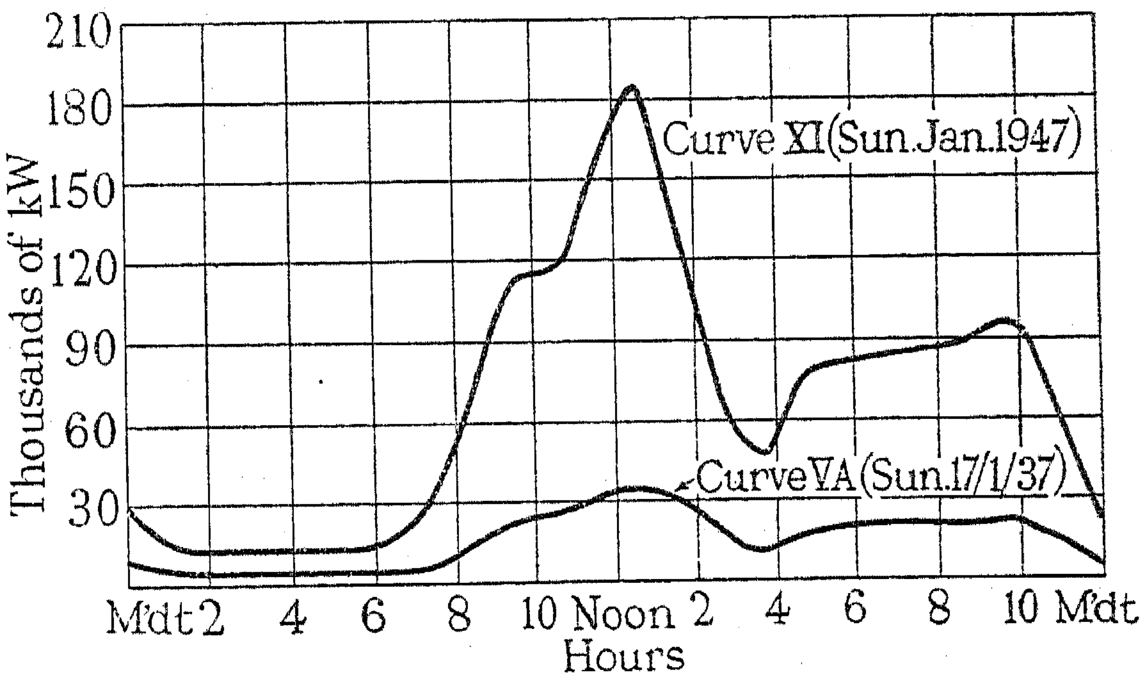


Fig. 8.—Load curve for winter Sunday in 1937, and hypothetical load curve for similar day in 1947.

A machine can be made more efficient at light loads, with a small sacrifice of efficiency at high loads, by some system of adjusting the area of the inlet nozzles. The first row of nozzles may be arranged in groups operated by valves, or may be bypassed at high loads.

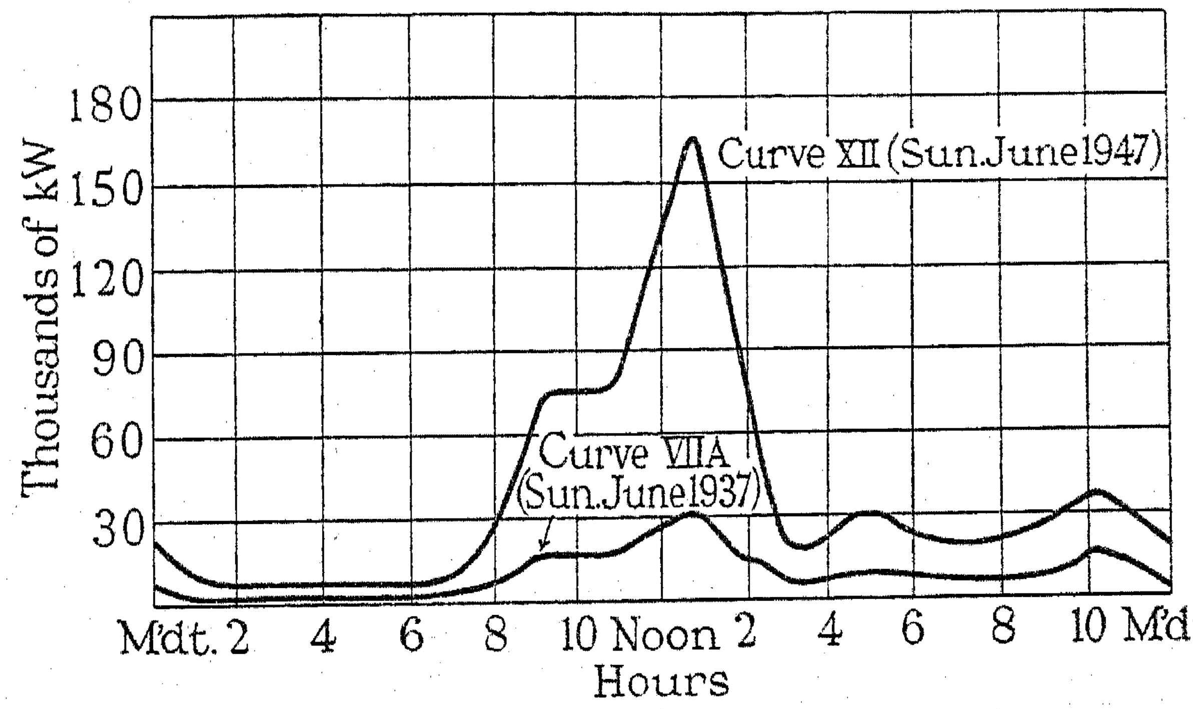


Fig. 9.—Load curve for summer Sunday in 1937, and hypothetical load curve for similar day in 1947.

Prior to operation with the grid an economical power station had 5 or 6 machines designed for best efficiency at 80 % of full load. Such a station on heavy load would run at the best efficiency of its turbines and yet have a sufficient margin to sustain the load if one set broke down.

EFFECT OF GRID OPERATION

Under grid operation there may be 100 machines running in parallel at periods of heavy load, so that the loss of one set would mean a loss of only 1 %. The control engineers of the grid make arrangements to start up and shut down plant to meet the variations of load, and it will be clear that if they can follow the load variations closely it becomes possible to run sets at heavy-load periods at nearly 100 % capacity.

At periods of light load, only a few base-load sets selected from stations of class " A " will run, and these turbines must have a margin of capacity and be equipped with some form of bypass or nozzle control.

The day-load turbines must be highly efficient because they generate half of the units. They should be designed to run always at 100 % load, and the most efficient turbine for this purpose would have plain throttle governing and no bypass or nozzle control.

The peak-load turbines have only to run short hours, and thermal efficiency must be subordinated to low capital cost. They must be simple in operation, suitable for quick starting, and cheap in first cost.

EFFECT OF LOAD EXPANSION

If the load expansion follows our estimates, base-load and day-load machines will be increased in size or numbers by two or three, but peak-load machines must be of an entirely different size and character. These peak-load machines will carry 50 % instead of 20 % of the maximum demand, and will generate 15 to 20 % instead of 1 or 2 % of the total units; moreover, they will have to carry maximum demand and generate units at times when circulating-water temperatures are high.

At the present time, peak-load machines meet only small lighting peaks in winter time, but we must now visualize sets of 30 000 kW to 50 000 kW capacity, i.e. as large as our present base-load machines, which can be run up and put into service for perhaps 1 hour. These sets will no longer be shut down at week-ends and during the summer; they will have to operate each day of the year, including Sundays, and since they will deliver a large number of units they must be comparatively efficient.

Class " C " stations are at present selected from those which by reason of size, age, or position, are inefficient. There will always be plant of this character worth retention for stand-by in emergency, but such plant will not be suitable to meet the kind of peak loads that will be experienced in the future. Peak-load sets will be necessary in every large generating station situated at the heart of a distribution network.

WATER FOR CONDENSING PURPOSES

A power station must be placed where there is sufficient water for cooling purposes. The scarcity of water in the Midlands is already such that much of the base load is carried on cooling-tower stations. By 1947, loads may have increased so much that the River Trent will not supply sufficient cooling even for the load of the City of Nottingham. Cooling-tower stations require water to make up for evaporation, and the evaporation for a given load is nearly twice as much in the summer as in the winter. When we consider that summer maximum demands will be multiplied 3 to 6 times, we must realize that the make-up to a cooling-tower station will absorb the flow of quite a large river.

Circulating-water conditions also have an important effect on plant capacity. In a cooling-tower station the cooling-water temperature on a hot day in summer may be 40 deg. F. more than on a cold day in winter, and the consequent loss of vacuum may be responsible for 10 % difference in steam consumption. It follows that 10 % more turbines and boilers would be necessary to carry the same load on the hot day than on the cold day. Ten years ago the winter peak load in Leicester was 30 % more than the peak load of a summer day; this year it was only 15 % more, and in 10 years the difference may be so little that more plant must be available to meet the summer peak than the winter peak.

DESIGN OF GENERATING SETS TO MEET PEAK LOADS

Under grid control a peak-load machine should be designed to run for a very short time at 100 % load, but it will be apparent to station operators that the large efficient machine of to-day is unsuitable for such a duty. It takes an excessive time to put into service, largely by reason of the extensive and complicated system of bled-steam feed-heating. It may be necessary to design the peak-load machine for non-bleeding.

An alternative would be to design a machine to run a longer time but capable of a large overload for a short time. Such an overload could be obtained by providing one or more by-passes to the nozzles at the high-pressure end of the turbine, but the resulting machine, although having a good efficiency at moderate loads, must have an inferior efficiency on overload. A considerable overload could also be obtained from a turbine normally bled for feed-heating by cutting off the bled steam, but again this means a loss in efficiency.

All these methods give an inferior efficiency at high loads, and therefore require additional boiler plant and condensing apparatus for use at peak load only; clearly a design to give maximum efficiency at maximum load would be more suitable even at the sacrifice of efficiency at moderate load.

The difficulty might be met by providing heat accumulators to work at times of peak load and be charged during light load. Heat accumulators consist of pressure vessels storing hot water, and I should say that such vessels must be very bulky to provide for any considerable load adjustment.

SALE OF STEAM

There are other possibilities. A few stations have found opportunities for selling low-pressure steam to industrial users for process work and for heating, to the benefit of themselves and the consumer, and this is a development which ought to be encouraged. Such an activity enables the supply undertaking to compete successfully for the power supply to factories at present generating independently from pass-out turbines.

The sale of low-pressure steam from a power station appeals to the imagination as a profitable method of disposing of waste low-grade heat, but there are other and more important advantages. A supply of steam for process work has usually a high load factor because of heat losses and the storage capacity of consumers' apparatus. What is more valuable is that there is diversity between the steam load and the steam required for electrical load, which improves the plant load factor of the boilers. The effect on turbines is also important. The high-pressure end of the turbine has to be enlarged to pass the additional steam which, after doing work, will be bled for external supply. The cost, and incidentally the limit of size, of a turbine is determined by the size of the low-pressure end, and therefore the sale of steam makes possible the building of turbines of larger output and cheaper first cost. The large size of the high-pressure end of a turbine designed for bleeding low-pressure steam permits the machine to give a very large overload if the bleeding is reduced. Thus the diversity between steam load and electrical load increases the overload capacity of turbine plant. The idea might be pursued further; just as off-peak electrical loads are encouraged, so may off-peak steam supplies be sought to improve the economic load of the supply station.

I suggest, therefore, that power stations in industrial areas will, in the future, be equipped with pass-out turbines to supply process steam and hot feed-water, and capable of meeting short electrical overloads by control of bled steam.

STEAM CONDITIONS

I would suggest that peak machines will need to be designed for the highest temperatures and pressures. According to our present ideas, it is uneconomic to employ high-pressure plant for peak loads, but the conditions we have examined demand an entirely different standard of plant construction. The peak loads we are now considering in a city of the size of Leicester can only be economically met by machines of the largest output. The size of a turbine is limited by the size of the low-pressure wheels, and it is only by increasing the pressures and temperatures that machines of large output and reasonable size can be designed. Moreover, evaporative capacity and condensing equipment are determined by the efficiency of the plant on the peak-load conditions, and the magnitude of boiler plant and cooling apparatus will so obviously limit the size of the 1947 power station that the highest efficiency must be sought.

COMBINATION OF BOILER PLANT AND TURBINE PLANT

At this point I must mention the trend in modern power-station design towards the "unit" principle, in which one boiler supplies one turbine and together, with the feed-heating, they form one complete unit which works independently of other plant. It may appear that my previous remarks do not contemplate development in this way, but such is not the case. For base-load or day-load plant the unit principle has many advantages and will probably become generally adopted.

For plant to supply peak load or low-pressure steam, the unit principle appears less suitable, but a modification may be useful. With the general rise in steam pressure, a common device to increase economically the capacity of a low-pressure station is to install high-pressure boilers supplying back-pressure turbines which exhaust into the existing steam ranges. Such plant, called a "top" in the United States, can conveniently be installed on the unit principle, and this arrangement facilitates the use of re-heating and high-temperature feed-heating.

A unit consisting of a high-pressure boiler and high-pressure turbine could be designed for quickly putting into service, and a station equipped with such units would be flexible in operation. The low-pressure sets require time for raising vacuum and for putting feed-heaters into service, and should run long hours. At light loads one high-pressure unit of boiler and turbine would supply several lightly-loaded low-pressure turbines, so that peak loads would be quickly met by running up another high-pressure unit. The arrangement favours the operation of large boilers and suffers less from the disadvantage of the unit system that turbine plant must be kept idle during periods of boiler overhaul.

CONCLUSION

I have discussed certain problems which may arise from hypothetical considerations of load expansion. These hypotheses may not be realized in actual experience, but on the other hand many other important problems have not been mentioned. I hope that the remarks I have made will serve as a reminder that power-station design has not yet approached standardization.

The evolution of power-station design has been temporarily disturbed by linking up with the grid, and many engineers have lost touch with generating problems, while others have lost interest. Nevertheless, wider experience has been acquired in handling large blocks of power, and meanwhile the supply industry continues to expand. There is now a revival in the building of power-station plant, and I would say that there seems to be ample scope for skilled engineering in future developments.

TEES-SIDE SUB-CENTRE: CHAIRMAN'S ADDRESS

By J. H. HAWS, Associate Member.

"THE EFFECTS OF THE RATIONALIZATION OF INDUSTRY ON INDUSTRIAL DISTRIBUTION"

(*Address delivered at* MIDDLESBROUGH, *6th October,* 1937.)

I propose to talk about the effects on industrial distribution of the present-day tendency to concentrate industry (or, to use the more general expression, to rationalize industry), and the very heavy concentration of power which naturally follows. It is not possible, of course, to state particular cases, and for this reason I shall make my remarks as general as possible.

Up to a comparatively few years ago, the distribution of electrical power beyond the point of supply, to any excepting very large consumers, was a matter of very little interest to the electrical industry. It was generally accepted that any problems lay in distribution to the supply point or, alternatively, in the power plant. Consideration had to be given to a means of distributing the actual load currents, and the consumers' apparatus was given the necessary current-carrying capacity and insulation for this purpose. The consuming plant being in general small, the working voltage tended to be low, and, provided that first-class apparatus was purchased, it became customary to forget the consumers' distribution installation as much as was consistent with the amount of trouble developed. With further increase in consumption the consumers' plant was generally expanded on the original lines, with perhaps the substitution of a low-tension switchboard for a fuse-board at the point of supply, and an increased capacity in the transforming plant or generating plant before the point of supply.

The supply authorities developed a technique in distribution based on a reasonable density of development, and the distribution apparatus was installed having regard to the short-circuit conditions then prevailing. It became a common practice to distribute power at voltages between 3 and 11·5 kV, with a short-circuit condition between 25 and 75 MVA, to consumers taking 500 to 1 000 kVA, which was generally transformed to 440 volts on the premises.

When there was considerable extension of the consumer's demand and extensive distribution of high-tension power on the consumer's premises, the consumer generally adopted the method of electrical distribution developed by the supply authority, and part of his network became an integral part of the supply system, subject to the short-circuit conditions prevailing at that point from time to time, and capable of disturbing the supply system when any fault occurred on his apparatus.

The consumer's network is now affected by changing generating and distributing conditions on the supplier's network, circumstances over which the consumer has no control and which may not affect him beneficially but which may tend to destroy his apparatus if and when a fault develops in his network. It would appear that the consumer could substantiate a claim against the supply authorities that they should take steps to safeguard his interest in this matter if and when they increase the short-circuit conditions for purposes other than for meeting his increased consumption.

When, as is often the case, the supply authorities have safeguarded their own interests by themselves installing the consumer's high-tension apparatus (at the expense of the consumer, either directly or in terms of their power agreement), then the power supply authorities appear to be liable for maintaining the short-circuit condition as originally designed, and in general they are found, with certain exceptions, to be willing to do so in these cases. It is important, however, that the consumer's engineer should have available information regarding the supplier's distribution conditions, so that he may ascertain that the short-circuit conditions are well within the scope of his apparatus at all times. I wish to emphasize strongly that no power agreement should be entered into that does not contain, in addition to all the usual definitions of maximum demand, load factor, power factor, voltage, frequency, etc., a definition of the maximum short-circuit condition which shall prevail at the point of supply.

There is another aspect of this matter which is concerning industry to a great extent at the present time. I refer to the rating (and also to the de-rating) of apparatus, particularly switchgear, in relation to its capacity to carry and to rupture fault current. Adverting for a moment to my remarks about the liability of a supply authority to maintain the designed short-circuit condition at the point of supply, the situation is somewhat complicated when it is found that the consumer's apparatus is not of the capacity necessary for the original short-circuit condition. It would appear that the owner of the apparatus is liable for the cost of installing apparatus to meet the original requirements, and the supply authorities for any cost beyond this. When the supply authority is the owner of the apparatus, as is sometimes the case with apparatus paid for by the consumer, the supply authority, unless there is provision to the contrary, becomes liable for all of the cost of bringing the apparatus up to present requirements. A very careful reading of the power agreements becomes necessary when a case of this kind arises.

It is only in recent years that switchgear testing stations have been available for the purpose of ascertaining the capacity of high-tension switchgear to rupture fault current, and it is still later that the importance of the conditions under which switches would be closed by the customer has been appreciated, as compared with the remote-closing devices necessary in a testing station. It will be appreciated that a hand-operated switch undergoing test to destruction could not be closed by hand in the test cell, and it was not until recently that the futility of endeavouring to close a switch by hand against the electromagnetic forces set up by fault currents between 10 000 and 50 000 amperes was appreciated. It is now recommended that hand operation should not be attempted when it is necessary to close the switch against fault currents of this magnitude, but if the switch is such that it can be permitted to be released at the first touch of the spark contacts, hand operation with a shock release may be used.

One result of the new testing stations has been to make available high-tension switches of known and consistently reliable performance under *test plant* conditions. In the matter of correlating the test plant and the system conditions, as regards the selection of switchgear, there appears to be some considerable difference of opinion; but it is thought that the recommendations* of the British Standards Institution (which have been awaited for some years) will provide a standard method of calculating the fault current and selecting a circuit breaker for use under any particular condition.

Another result of the new testing stations has been to ascertain the actual capacity of gear which previously had been rated in terms of its general performance in situations where the calculated short-circuit current gave to the gear its nominal rating. Practically every type of circuit breaker so rated has proved to be incapable of justifying this rating on the test plant, and only those designs which had been developed by service under arduous conditions have remained as current designs after the searching tests to which the test plant has subjected them. Even designs which gave a reasonable breaking capacity have been found to be deficient as regards closing capacity, and the older designs, using porcelain insulators, have been found difficult to modify, because of the shock due to the great difference between the closing force necessary with no current, and that necessary under short-circuit conditions. In many cases the solenoids of remote-operated switches have been found to be inadequate against the forces resisting closing, solenoids of as much as four times the power provided being necessary, and the existing design of mechanism has been found to be obviously inadequate for modification.

The position with regard to switchgear which has not been subjected to test, but has been de-rated in terms of the designers' opinions, as influenced by consideration of other designs which *have* been tested, is still less satisfactory. A considerable number of designs have been abandoned, after the apparatus has been in service for some time, for diverse reasons, the commonest being that a better design was found in course of time. As there is no probability of selling more of these designs, the manufacturers are averse to submitting them for test. In many cases it would be necessary specially to manufacture a sample for this purpose, and the cost of this, together with that of carrying out the test, is considerable. Customers are therefore being asked to accept arbitrary ratings, which, in view of the present situation that has developed from previous acceptances of this nature, they are naturally reluctant to do.

It is not always appreciated that switchgear sold, as recently as two years ago, as of a certain rupturing capacity, has since been admitted to be inadequate for that rating, and it is suggested now that customers should end this unfortunate situation by close specification and a demand for a type-test certificate, or alternatively indemnification if a subsequent type-test proves the inadequacy of the apparatus.

This, generally, is the situation regarding high-tension switchgear. What to do about it is a problem which is exercising the minds of a considerable number of industrial (and other) engineers at the present time. A wholesale rejection of immense quantities of switchgear which has in many cases proved equal to the demands on it over a considerable number of years, does not make a strong appeal to the industrial engineer, but it cannot be denied that freedom from faults of major magnitude in the past will not preclude them from happening in the future. Therefore, knowing the maximum short-circuit current which can occur, it appears necessary to decide what proportion of this it is reasonable to cater for, and to adjust the position accordingly. In some cases it is possible to insert reactors so that the short-circuit current is reduced; in others it will be necessary to replace the switchgear. In either case industry in general is faced with considerable expense in connection with the de-rating of switchgear, and it is necessary that this problem should be ventilated as freely as possible in order that a uniform policy should be arrived at, rather than each individual being stampeded into independent action.

I next propose to review the low-tension switchgear situation.

It is safe to say that it is only within the last year that proper attention has been given to the short-circuit capacity of low-tension switchgear. The short-circuit testing stations have been occupied with considerations of high-tension design. This is natural, considering that this was their primary purpose, and that there has been a greater expansion in high-tension distribution during the last few years than during all previous time. The necessity for investigation of the low-tension situation has arisen from the greater concentration of low-tension load, due in part to general expansion in industry, and in part to the modern "rationalization" of industry which so often takes the form of geographical concentration of associated industries with common services of steam, electricity, water, etc., or increased expansion of one favoured site by the shutting-down of others. However the expansion is secured, the continuance of technique formerly in use has resulted in many cases in concentrations of low-tension power whose calculated short-circuit values are greatly in excess of the capacity of any tested low-tension switch; in fact some low-tension concentrations have occurred in which reputable manufacturers have experienced difficulty in providing apparatus to cater for the normal load current alone.

While this may sound very alarming, I must point out that my comparison is made between the short-circuit capacity of switchgear as ascertained by actual tests, and the system short-circuit currents as calculated by the conventional methods. I should like, now, to emphasize that there is a considerable difference of opinion as to the general accuracy of calculated low-tension currents when the conventional methods, which admittedly serve very well for high-tension circuits, are used.

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* Draft B.S.S. No. 116 (revised).

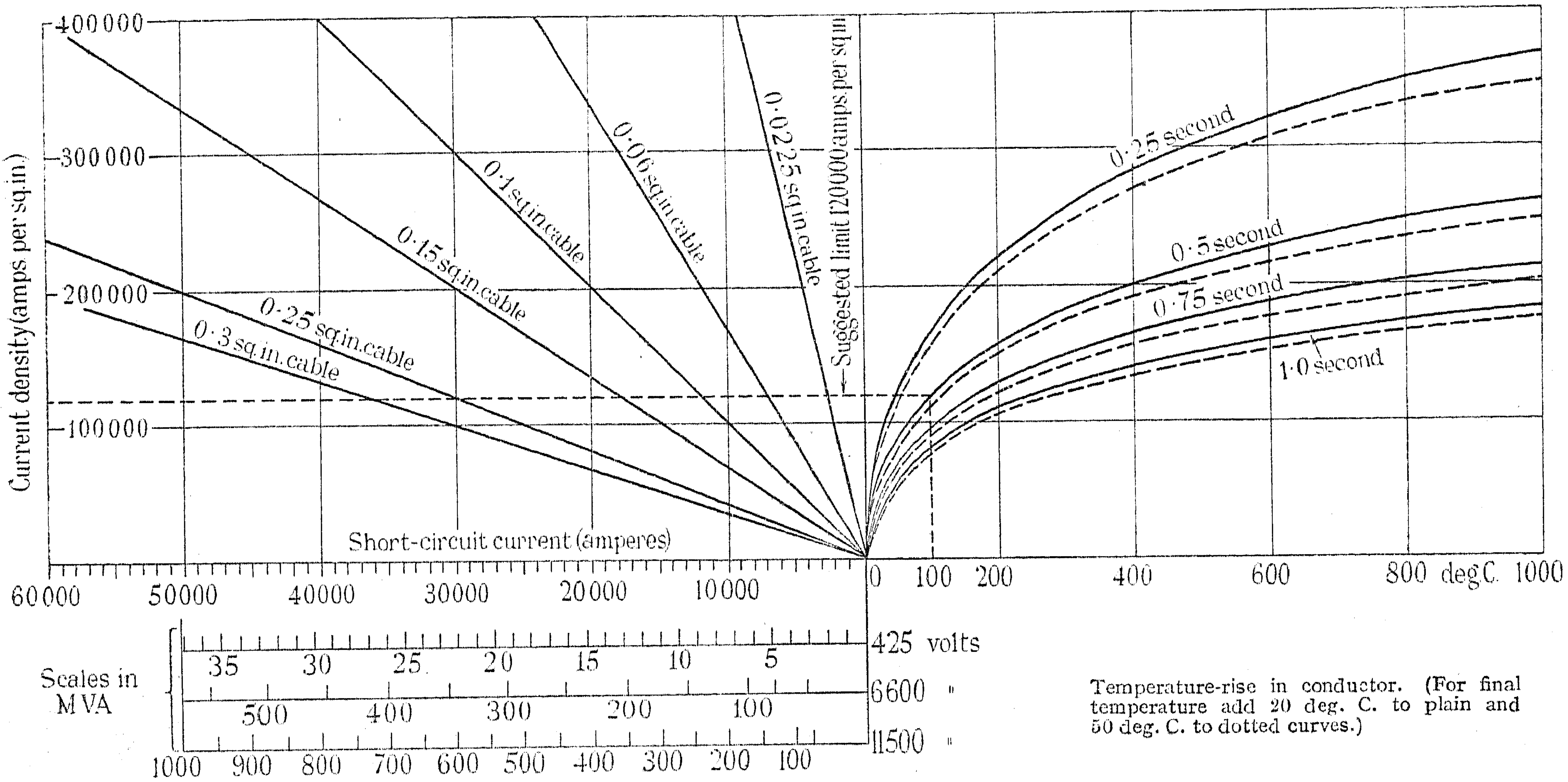
It is generally admitted that the short-circuit current, like any other, is a function of the e.m.f. acting over the impedance of the circuit, and that the impedance of a high-tension circuit can be determined with sufficient accuracy for our purposes. It is also generally accepted that the effect of small extraneous impedances, while negligible in a high-tension circuit, will form an appreciable part of the total impedance of a low-tension circuit. The extraneous impedances may be provided by unconsidered connectors and the resistance in contacts, etc., which are admittedly difficult to assess. While this is perfectly true in the case of small installations, it does not hold to the same extent in the case of large installations where the correct estimation of the short-circuit condition is of very much greater importance. Reasons for this are not difficult to find. A large installation will undoubtedly contain relatively large units of transformation plant, and as they will have low-tension connections of considerable cross-section it is natural that the lengths of these connections will be minimized in the layout of the plant. In fact it is not uncommon to have the transformers placed so that their low-tension terminals are adjacent to the switchgear; the high-tension cable (offering considerably greater flexibility) is extended accordingly, but the effect of the increase in impedance of the h.t. circuit is negligible. On the other hand, a small transformer of, say, up to 500 kVA capacity might be located in any convenient position, and the low-tension cable from the transformer to the switchgear would offer a considerable contribution to the total impedance.

There can be no doubt that it is easier to ascertain the actual short-circuit rating of a low-tension switch than to assess the short-circuit condition on a network, with a view to selecting the appropriate apparatus for use thereon. It is therefore essential that the subject be kept under constant review until there is some uniform policy with regard to selection. In the meanwhile it must be admitted that anyone concerned in the design and layout of a low-tension network is in an invidious position, so long as there is the probability of subsequent discoveries rendering his design obsolete and involving a considerable expenditure, shortly after the installation is completed, assuming, of course, that it would be considered necessary to bring the network up to the standard then considered to be desirable.

It appears, therefore, that as there are now three (and there will shortly be four) testing plants in this country, the obvious course of action is to specify that all types of l.t. switchgear used for distribution purposes should be rated for making and breaking capacity in exactly the manner specified for high-tension apparatus, i.e. by actual test, in order that there may be no necessity to revise this rating at a later date. This would permit any necessary changes being made by adjustment of the impedance of the circuits, if subsequent change in policy calls for a reduction in the short-circuit current. It cannot be too clearly appreciated that some of the ratings applied to l.t. switchgear which has not been submitted to test are very considerably in excess of those which would be given after testing, and that there are many designs whose closing mechanism is entirely unsuitable for closing on to a fault current considerably less than that which the circuit breaker could rupture with safety. There can be do doubt, therefore, that the continued purchase of apparatus which will become obsolete in the near future is extremely unwise and that a general demand for proved ratings will result in a considerable improvement in design.

Another section of the low-tension networks which I must not omit to mention, but which I am afraid must be dealt with in summary fashion, is the motor starter, or other switch of this nature, where the concentration of power is such that there is a relatively high short-circuit condition, notwithstanding the appreciable effect of the impedance of the low-tension cables. Here again the concentration of power into a small area robs us of the safeguard afforded to a small system by the higher impedances of small cables. It is no uncommon practice to use very short runs of, say, two 0·4-sq. in. cables in parallel, to a sub-distribution board, and it is found, therefore, that the short-circuit condition at the control gear of a small motor may bear very little relationship to the size of the motor. As the motor and its control gear may be moved about the system, or it may be necessary to provide apparatus of a standard design, it appears desirable to cover the short-circuit condition by providing a high-rupturing-capacity fuse, and this is best located at the sub-distribution board, which might well take the form of a high-rupturing-capacity fuse-board. The latter should be regarded as for the joint purpose of isolation and fault-current rupturing. The overloading of the motor (or such apparatus) should be safeguarded by an appropriate device on the control gear, and the normal current ratings of the fuse should be the maximum for the fuse-way and not reduced to correspond to the load current. The extremely low operating times available in these fuses will ensure that the fault current is ruptured at this point even when the control gear has an inverse time-limit device which reduces the overload setting to a minimum; and the control gear will be submitted to only the mechanical shock of the straight-through current, unless, of course, the source of the fault current is in the control gear.

The use of high-rupturing-capacity fuses will doubtless commend itself as a "back up" protection in the case of low-tension distribution switchgear which is found to be subject to greater short-circuit conditions than are reasonably safe. As regards rupturing only, it is undoubtedly a solution, but it remains to be determined whether the closing conditions are reasonably safe, though there is a reasonable expectation that this will be so. Considerations of mechanical damage due to the fault current need not arise, provided that they do not seriously affect resumption of supply, and that there is no such damage between the fuses and the source of supply. High-rupturing-capacity fuses cannot, therefore, be accepted blindly as a solution for this problem, but there is no doubt that in many cases, suitably applied, they will save considerable expenditure on replacement of de-rated switchgear. It may be found necessary to mount the fuses on, say, the back of the busbar casings, and to divert the switch connections from the busbars direct to the fuses. Here again there is an advantage for only medium-size circuits, as the highest normal current ratings in high-rupturing-capacity fuses at present available are inadequate for the larger circuits. It is not probable that high-rupturing-capacity fuses of really heavy normal-current ratings will become available, as these would appear to be rather in the nature of a bomb, and a failure to operate successfully under short-circuit conditions would probably result in an explosion. Nevertheless, the high-rupturing-capacity fuses have a wide field of application, provided that they are brought and installed with care. Many of those available will generally function according to their rating, but it is unwise to accept the ratings of any types which have not been subjected to test at the current and voltage on which they are to be used.



Temperature-rise in conductor. (For final temperature add 20 deg. C. to plain and 50 deg. C. to dotted curves.)

Fig. 1.—Curves showing relationship between short-circuit current and final temperature of conductor.

Plain curves based on an initial temperature of 20° C.
Dotted curves based on an initial temperature of 50° C.
Assuming no loss of heat.

I think that there is sufficient in the foregoing remarks to indicate that a considerable amount of trouble arises from the concentration of power at such voltages that the short-circuit currents are excessive. I should like now to draw your attention somewhat briefly to some other effects of heavy currents on a distribution system. I have prepared a series of curves showing the relationship between current and temperature-rise in copper conductors (Fig. 1). The calculations assume that the current is uniform throughout the time considered, and that the time is too small for any loss of heat from the copper. The left-hand horizontal scale represents current, and to this are attached the various kVA scales at the appropriate voltages. The right-hand horizontal scale represents the temperature-rise in the copper in deg. C. The vertical scale represents the current density in amps. per sq. in., and the relationship between this and the fault current is obviously a matter of the size of the conductor under consideration. The relationship between the current density and the final temperature is, of course, a matter of time. The maximum permissible temperature-rise is determined by the nature of the dielectric, and I would suggest that, for cables, a value of 100 deg. C. is not conservative. The curves, subject to their limitations, show that this temperature-rise is attained in 0·5 sec. with a current density of 120 000 amps. per sq. in., and an initial temperature of 20° C., i.e. a final temperature of 120° C., which is excessive for paper and rubber insulation.

I would suggest that a current density of 120 000 amps. per sq. in. is the maximum permissible, and this means that 120 000, multiplied by the section of the cable in square inches, determines the maximum short-circuit current which may be carried by that particular cable. Reference to the kVA scales relative to the current and voltage will show that the minimum size of cable permissible is considerably greater than is in common use, and that the use of small cables in situations subject to heavy short-circuit currents might well lead to absurdly high temperature-rise. I should like to make it clear that the curves are calculated (making due allowance for the exponential effect of change in resistance) and are not based on observation of temperature-rise under short-circuit condition. I think that it would be extremely interesting to compare such observations with the calculated values, and would suggest that this is a matter for co-operation between the Cable Research Committee and one of the short-circuit-testing stations, who alone can provide the heavy current neces-

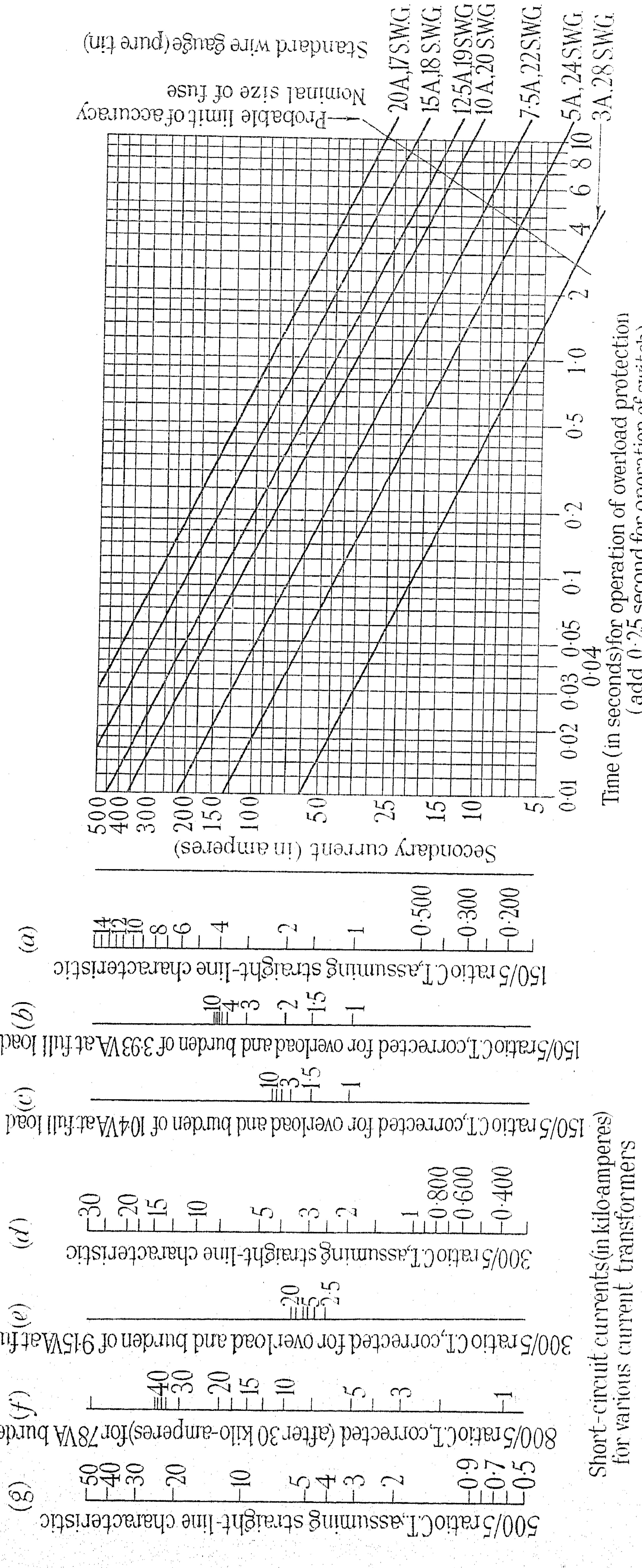


Fig. 2.—Relation between fault current and time taken to operate time-limit fuse type of overload protection.

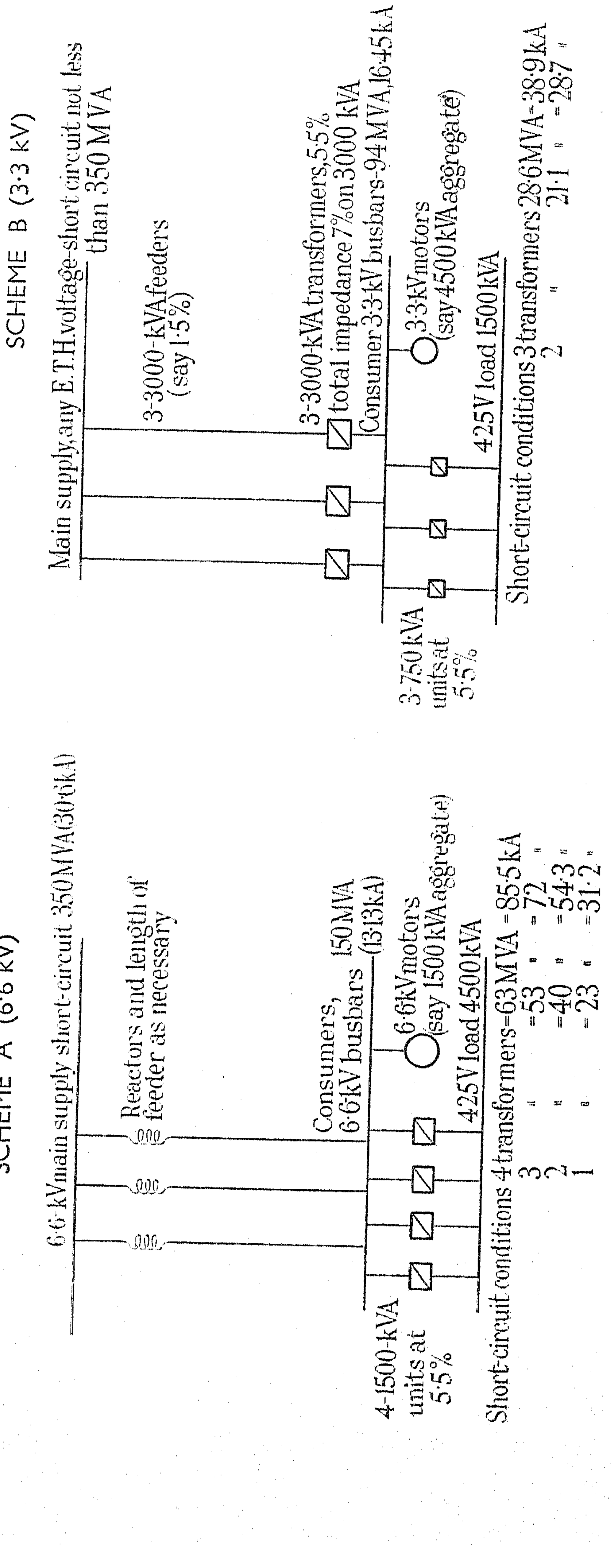

SCHEME A (6·6 kV)
6·6-kV main supply short-circuit 350 MVA (30·6 kA)
Reactors and length of feeder as necessary
Consumers, 6·6-kV busbars 150 MVA (13·13 kA)
6·6-kV motors (say 1500 kVA aggregate)
425V load 4500 kVA
4-1500-kVA units at 5·5%
Short-circuit conditions 4 transformers = 63 MVA = 85·5 kA
3 " = 53 " = 72 "
2 " = 40 " = 54·3 "
1 " = 23 " = 31·2 "
SCHEME B (3·3 kV)
Main supply, any E.T.H. voltage short-circuit not less than 350 MVA
3-3000-kVA feeders (say 1·5%)
3-3000-kVA transformers, 5·5% total impedance 7% on 3000 kVA
Consumer 3·3-kV busbars-94 MVA, 16·45 kA
3·3-kV motors (say 4500 kVA aggregate)
425V load 1500 kVA
3-750 kVA units at 5·5%
Short-circuit conditions 3 transformers 28·6 MVA-38·9 kA
2 " 21·1 " = 28·7 "

Fig. 3.—Alternative arrangements for a 6 000-kVA supply.

sary for this purpose. The next most serious effect of too-heavy fault currents, in my opinion, is in connection with the protective gear which is operated by fault current. In general these devices use current transformers which, in the past, have been designed in terms of their normal load currents, and which find themselves under totally unsuitable conditions when subjected to the heavy primary currents that are now all too common.

It is not intended to review the whole subject of protective gear in this Address. That would be impossible as the subject is much too extensive, and in any case it would need a specialist to do it justice. I should, however, like to draw attention to the effects on the older method of protection due to the generally increased short-circuit currents.

I think that it is safe to say that the purpose of protective apparatus is primarily to safeguard the remainder of the system under fault conditions, and secondly to minimize damage to the faulty apparatus by disconnecting the faulty apparatus as quickly as possible. While the excess of fault current does not necessarily impair the second requirement, its effect on the stability of protective circuits on sound apparatus carrying straight-through fault current and on the time settings of the old-fashioned inverse time-limit-fuse overload protections used for the graded discrimination is such that, under the conditions supposed, there is generally an indiscriminate opening of switches, with unnecessary limitation of supply, and general confusion. For instance, the Merz–Price balanced-voltage feeder protection becomes unstable at the now relatively low fault current of 8 000–10 000 amp., but I understand that some additional apparatus is available which will increase the stability of this form of protection to approximately three times this value with only a moderate increase in the fault setting. With regard to the inverse-time-limit fuse type of overload protection, I have prepared another set of curves (Fig. 2) which purports to show the time between the incidence of the fault and the operation of the protective gear, having regard to the current transformer and the size of pure tin wire used as a time-limit fuse. These curves have considerably greater limitations than the former ones as they were prepared in 1930 from our limited knowledge of the effect of burden on the ratio of the current transformers and also the effect of approaching saturation. The tin fuse-wire, also, has been considered as not being subject to loss of heat by conduction or radiation. The curves are therefore of use only for comparative purposes in obtaining discrimination between two overload protections in series, but it will be seen that discrimination can be obtained only under load conditions and not under fault conditions. It becomes necessary, therefore, to use a definite time-limit device if over-current discriminative tripping is required, and this generally means special relays and their tripping batteries, etc., where the older type of a.c. trip gear was in use.

I think that it has been stressed sufficiently that the major trouble which accrues from excessive concentrations of electric power, and indiscriminative expansion on the conventional lines, is simply too much current under short-circuit conditions, and it becomes necessary to take this into consideration in our designs for future layouts and modifications of those existing. The simplest method is to increase the working voltage, and, with larger units of industrial application becoming common, it becomes easier to collect a considerable proportion of the plant which would have been arranged for low tension, say at 400 volts, and to use 2 200 or 3 300 volts instead. In this connection it should be noted that motors of as low as 50 h.p. can be obtained for use at 2 200 or 3 300 volts, and with increase in demand there is no doubt that the limit could be further reduced. There will, of course, be a residue of small motors, etc., which would of necessity be of low tension, but unless there is a high percentage of small units it would not necessitate a low-tension system of sufficient size to produce the heavy short-circuit current to which reference has been made.

The alternative, if this were the case, would be to split up the networks to a maximum of 2 000–3 000 kVA installed capacity of transformers in each section, keeping each section isolated, and distributing in the conventional manner. There is no doubt that sufficient sectionalization of a heavily concentrated load would give rise to considerable extra expenditure in the first cost of the layout, and would cause many of the advantages of handling power in bulk in the conventional manner to be lost.

It may be argued that the introduction of an intermediate high voltage would result in an additional group of switchgear, i.e. extra-high tension, intermediate high tension, and low tension, for industrial distribution purposes. I would suggest that in many cases the extra-high-tension equipment could be eliminated by installing e.h.t./l.t. transformers in the feeder equipments from the source of supply. The first available voltage at the "industrial" end of the feeder would then be the intermediate high tension, and the short-circuit condition would be reduced according to the impedance of the transformers. There is, of course, nothing very novel about this proceeding, but a more general application would assist in those numerous cases where the h.t. voltage is too high for industry except for very large powers, and the l.t. voltage is too low. In many cases the high-tension distribution system voltage is reduced to, say, 6·6 kV in an endeavour to cater for industrial purposes, but this is too high for general use, and too low for e.h.t. distribution, if the short-circuit condition is likely to exceed 350 MVA. It appears improbable that a load of 30 000 kW or more would be concentrated at one switchboard without the short-circuit condition reaching 350 MVA. There are many industrial concerns, and considerably more distributing undertakings, where concentrations of power of this magnitude are at 6·6 kV. I wish to suggest that this is the limit for such a relatively low voltage, and in any case where this amount of power might be exceeded distribution should be at 11·5 kV or higher.

Fig. 3 shows alternative arrangements of a supply of 6 000 kVA at 6·6 kV. Scheme A is the conventional arrangement, and Scheme B shows the step-down transformers included in the feeders. The main supply pressure for Scheme B could, of course, be of any voltage desired, and if higher than 6·6 kV the advantage would be increased.

HAMPSHIRE SUB-CENTRE: CHAIRMAN'S ADDRESS

By W. F. RAWLINSON, D.Sc., Member.

"PROBLEMS IN WIRELESS COMMUNICATION"

(ABSTRACT *of Address delivered at* PORTSMOUTH, 13*th October*, 1937.)

The problem of reception of wireless signals is of almost universal interest. Wireless telegraphy or telephony is the only means of communication with ships at sea and with aeroplanes; it has taken its place as part of a world-wide telephony system; business communications, news, and pictures are transmitted to all parts of the world; and last, but by no means least, the broadcasting organizations provide entertainment and instruction for a large proportion of the population of every country. In every case successful communication depends upon the ability to receive wireless signals in an intelligible form. It is of some importance, therefore, to consider the factors which, at the present time, set a limit to the attainment of this object.

The problems involved in wireless reception may be roughly divided into two classes. The first of these classes embodies the difficulties which arise in receivers themselves; the second, those introduced by the medium through which the waves are propagated. In order to separate them it is necessary to form a mental picture which will represent what is being radiated and received. So far as pure receiver problems are concerned, it is sufficient to assume that the receiving aerial is called upon to accept plane electromagnetic waves propagated over the surface of the earth, and to assume further that the earth itself is a perfect conductor. Under these conditions, an electromotive force at the same frequency as that of the incoming waves will be generated in the aerial of the wireless receiver, and the problem of reception is limited to the amplification and final detection of this induced electromotive force.

Modern wireless telegraphy and telephony began with the use of the hard valve with its controlling electrode or grid. In the simplest theory of the operation of receiving valves, provided the grid is maintained at a sufficiently negative potential relative to the amplitude of the oscillating e.m.f. imposed upon it, the valve acts as a pure amplifying device, requiring no power from the input circuit, the power developed in the anode circuit being produced by local sources. Under these ideal conditions there would be no limit to the amplification which it would be possible to obtain by the use of valves in cascade, or to the smallness of the input signal which could be detected. In practical valves, however, the electrodes are close together and there will be mutual capacitance between them. When this is allowed for, the impedance between grid and cathode is no longer infinite and the input voltage is actually working into an impedance with a resistive component, so that it is no longer possible to amplify the voltage without taking power from the source of supply. This at once limits the amplification which can be obtained from a single valve, and also makes it apparent that, since there is coupling between the anode and grid, it will no longer be possible to build up an indefinite number of stages of amplification, owing to this back coupling resulting in uncontrollable oscillations. Although, in practice, the triode valve has almost disappeared in favour of tetrodes and pentodes, so far as high-frequency amplifiers are concerned residual capacitance between electrodes still sets a limit to the amount of amplification which can be attained with stability, and therefore a minimum input voltage to any amplifier will be required to produce a given output.

The most serious limitation arising in the case of wireless telephony reception is provided by the number of stations which desire to work in a limited band of frequencies. When a broadcast transmitter is switched on, but no programme is being radiated, it emits a carrier wave which is practically a pure continuous wave. Intelligence is conveyed by modulating this carrier with speech or music frequencies, i.e. the amplitude of the carrier wave is made to vary at the frequency of the modulation. This modulation results in the radiation of a band of frequencies. The ear is sensitive over a frequency band of about 50–20 000 cycles per sec., and this range of frequencies certainly occurs in the output of a full orchestra. Hence, if the carrier wave is being perfectly modulated by a full orchestra, the frequency band required by the transmitter will be at least ± 20 kc. per sec. on either side of the carrier wave. For perfect reproduction the receiver and aerial system must therefore be capable of accepting this wide frequency band. All the nations of Europe desire to use high-power broadcasting stations, however, and by international agreement their carrier frequencies are separated by only 9 kc. per sec. If, therefore, a receiver were used which would accept side bands ± 20 kc. removed from its own carrier, it would also accept the carriers and side bands of four other stations at the same time. It is fortunate, therefore, that to obtain reasonable reproduction it is not essential to transmit or accept side bands much above 7 kc. per sec., and a practical receiver must be limited to the acceptance of a frequency band of about this order. This sets the first serious limitation to the perfect reception of radio-telephony.

A second limitation is imposed by the demodulator valves. Owing to the properties of such valves, modulation depths of more than about 80 % maximum cannot be used at the transmitter, thus reducing the amount of contrast between loud and soft passages in any musical reproduction.

In all but local-station reception, telephony signals are in general subject to the phenomenon known as "fading." In the modern receiver an attempt is made to overcome this difficulty by the fitting of automatic gain-control devices which will result in the application of an approximately constant voltage to the signal demodulator, whatever the strength of the incoming signal. Whilst this device is satisfactory in the reception of signals which are not too weak and not fading too badly, on weak signals it tends to introduce distortion into the audio-frequency output, due to non-linearity of valve characteristics. Further, since a wireless receiver always receives noise as well as signals, although the signal output may be nearly constant the background noise rises and falls, with the result that all programme value may be lost.

The principles underlying the reception of wireless telegraph signals are somewhat different. All modern high-power telegraph stations, whether on shore or on board ship, emit continuous waves. Intelligence is conveyed by switching the transmitter on and off in accordance with some prearranged code, such as the morse code. The emission from the transmitter is therefore in the form of a series of trains of high-frequency oscillations, separated by spaces or silence. Again, one of the major problems which arises is the reception of the particular signal required to the exclusion of all unwanted signals, and once again the whole frequency band available is filled by stations. The type of selectivity required is very different from that in the broadcast receiver. In the case of the high-frequency circuits there is no need to pass a wide band of frequencies unattenuated, and every endeavour must be made to pass the narrowest possible band consistent with high amplification and stability. A further essential difference arises from the fact that no audio-frequency modulation is applied at the transmitter, and in order to obtain an audio-frequency output from the receiver the principle of heterodyning is generally employed. This has the great advantage that the frequency of the output signals is entirely at the choice of the operator, and additional selectivity can therefore be obtained by the addition of note-selector circuits after the demodulator valve. The amount of note selection which can be used is ultimately limited by the distortion which the circuits introduce into the shape of the dots and dashes.

It is interesting to consider at this point whether there is any phenomenon in the receiver itself which limits the weakest field strength which could be received, assuming no interference from any external source. In order to consider this question it is necessary to refer to the properties of matter. The circuits of all present-day wireless receivers involve the use of inductances, condensers, and resistances, and the inductances and resistances are conductors of electricity. Theory suggests that in every conductor small electromotive forces will be generated by thermal agitation, and if a tuned circuit or resistance is connected between the grid and filament of a valve these electromotive forces will give rise to changes of potential at the grid. Thus, even if no external source of e.m.f. is applied, the circuit connected between grid and filament of the first valve will, in itself, generate noises. There would thus appear to be a final limitation to the field strength which could possibly be received due to the properties of matter itself, since the noise-level of the receiver cannot be reduced below that generated by thermal agitation in the first circuit.

So far the difficulties encountered in receivers themselves have been considered, but these are not the only problems which arise. The assumption of plane electromagnetic waves travelling over the surface of a perfect conductor is not even a first approximation to the truth, and some explanation is required of the reason why wireless waves can travel right round a spherical surface without excessive attenuation. The explanation lies in the properties of the upper atmosphere. The problem of the propagation of wireless waves has led to most extensive researches into these properties during the last decade, and the results obtained by means of wireless observations have immensely increased the knowledge of the state of the medium surrounding the earth up to a height of several miles. The results show that, owing to the action of ultra-violet light from the sun, and the action of cosmic rays, the upper atmosphere must be ionized and must therefore behave as a semi-conducting layer. When an attempt is made to propagate electromagnetic waves through such a semi-conducting layer, it can be shown theoretically that the waves must suffer refraction, and the direction of the bending is, in general, such as to bend them back again towards the surface of the earth. Thus, in the simplest case it is possible to conceive the propagation of waves as taking place between a semi-conducting earth and a semi-conducting layer at a height of several miles. The waves are therefore, as it were, being propagated between two parallel conducting spheres. In the case of very long waves, such as those emitted by a transmitter like Rugby, this simple explanation is sufficient to account for the major points in the method by which the waves can cover practically the whole earth's surface. When, however, much shorter waves are considered, i.e. waves below about 200 metres in wavelength, additional effects begin to make themselves obvious. The most noticeable of these is the fact that signals can be received at short distances from the transmitter, after which there is usually a considerable distance over which no signals can be received, followed by a further area or areas over which signals can be detected. The method of explaining these results is that although the energy may be radiated from the transmitting aerial parallel, or at small angles only, to the surface of the earth, part of it must soon leave the earth and penetrate the upper ionized layers. Part of it, however, will travel as though the foot of the wave were tied to the earth. This latter part suffers heavy attenuation over the earth's surface, and therefore has a very limited range. The part which has penetrated into the upper atmosphere will, in general, be subjected to the effects of refraction and will tend to return to the earth's surface again. Depending upon the wavelength propagated and the ionization density of the medium through which a wave is travelling, and the effective height of the ionized layer, the wave will return to the ground after some finite distance of travel. If this distance is greater than the distance which the ground wave has travelled before being extinguished, then the effects of skip distance will be apparent.

In considering the ionized layer or layers, it is important to remember that the earth behaves as a large magnet and produces a magnetic field around itself. Theory shows that if a plane-polarized electromagnetic wave is transmitted through an ionized medium on which a magnetic field is superimposed, the resultant electromagnetic wave leaving this ionized layer will no longer be plane-polarized. The medium will, in fact, behave as though it were doubly refracting. Thus, whilst a single ray enters the medium, two rays with different polarizations and, in the general case, travelling with different velocities will be propagated through it and will emerge from it. This would be the case if the ionized layer through which they are travelling were itself homogeneous, but in considering waves which are travelling over large distances it has to be remembered that the local time of day is changing at every point in the path, in the case of east-to-west propagation, and that the sun's altitude is changing in the case of north-to-south propagation, so that there must be in all conditions a considerable lack of homogeneity in the medium. Due to this, the waves reaching the receiving aerial will be very complex in character, with the result that long-distance communications on short waves are subject to severe fading at more or less frequent intervals.

If, on the other hand, the effects are considered at distances for which the ground wave is still appreciable, and if the wavelengths are such that the indirect wave can reach the receiver as well as the ground wave, then, apart from any irregularities in the indirect ray, there will be interference effects between the direct and indirect rays, and the phenomenon of fading is again encountered.

So far as reception of broadcasting signals is concerned, propagation by means of rays reflected from the upper atmosphere has another serious consequence, especially in the medium-frequency band of wavelengths. In order to obtain really good quality over the so-called "service area" of the various medium-wave stations, high powers are used, but although the service area of each station is limited the indirect ray may reach the earth again after travelling several hundreds of miles in the upper atmosphere, and thus cause interference to receivers located far outside the service area. This effect is particularly noticeable at night in the case of British and European broadcasting stations.

As previously pointed out, the ionized layers are far from homogeneous, and when waves are travelling through a non-homogeneous medium it is well known that the velocity of propagation may be different for different frequencies. Now in the case of wireless telephony the carrier and side frequencies occupy an appreciable frequency band. When this band of frequencies is travelling through the ionized layer it is probable that at some periods the velocity of the various waves will differ. In that region where both direct and indirect rays are being received at the same time, owing to this change in velocity of propagation of different frequencies, some frequencies will be reduced to a minimum by interference effects, whilst others are brought up to a maximum. It is thus quite conceivable that at times the carrier wave may entirely fade out, whilst the side bands are at normal strength or are even reinforced. Under this condition the demodulator valve of the receiver will produce most obvious distortion, even though the receiver is fitted with automatic gain control.

In the case of telegraph reception the same problems of fading occur, owing to the fact that the waves are being propagated through an ionized layer and they assume even larger proportions, owing to the fact that shorter waves and higher frequencies are used mainly for very-long-distance communication, where reception depends solely on the indirect wave propagation. The waves may not even reach the receiver after a single reflection in the ionized layer. They may have undergone several reflections, both in the ionized layer and at the surface of the earth, before actually reaching their destination, hence still more irregularities are introduced.

Communication between England and New Zealand shows that it is possible for high-frequency waves to be transmitted half way round the world, and this in itself suggests the possibility that waves may be transmitted right round the world. Practice shows that this is actually the case, and receiving stations can, at times, receive a combination of waves, some of which have travelled the shortest distance from transmitter to receiver, others which have travelled the opposite way round the world, and still others which have actually gone right round the world once, or several times, before being received. Since the velocity of propagation of the waves is finite, it follows that those which have taken the longer paths will arrive later than those which have taken the shortest path, and the receiver will, therefore, receive echoes or ghosts of the transmitted signal. These echoes may be so powerful and so long delayed as to render reception difficult and at times impossible, owing to the way in which they fill up the spaces between the morse symbols.

Apart from questions of propagation of the required signals, one of the most serious limitations to the reception of either wireless telegraphy or telephony is the question of atmospherics. In the simplest possible theory, thunderstorms are caused by clouds becoming charged to very high potentials and then discharging, either to one another, or to the earth, in the form of lightning flashes. The lightning flash is therefore, in its essentials, an enormous spark between two electrically charged bodies. It has been estimated that the earth experiences 16 000 000 thunderstorms per annum, or 44 000 per day, and if it is assumed that each storm has an average duration of one hour there will be 1 800 thunderstorms in progress simultaneously over the earth's surface at all times. Since an active storm produces about three lightning flashes per minute, there will thus be about 100 lightning flashes over the earth every second. Recent measurements suggest that the average thunderstorm expends 2 or 3 million kilowatts of power continuously throughout its hour or so of activity, whilst the combined thunderstorms of the world are expending power at the rate of about 4 000 million kilowatts. Each lightning flash may be regarded as a spark-gap about 3 kilometres in length, with a potential of the order of 1 000 million volts applied to it, and each flash must give rise to an electromagnetic pulse. Thus, the atmosphere must be regarded as one continuous high-power spark transmitting station. Fortunately for the possibilities of wireless communication, the lightning pulses may be regarded as mainly unidirectional, and the electromagnetic waves generated by them suffer heavy attenuation when travelling over the earth's surface. In England, the effects of any but local thunderstorms are not sufficient completely to obliterate wireless signals, but in places abroad, such as Aden or Jamaica, periods of several hours per day occur during which wireless reception is virtually impossible.

Progress in the electricity supply of this country has resulted in power-supply companies erecting large overhead systems of wires (the grid scheme) carrying alternating current at very high voltages. These lines are, in general, insulated by means of porcelain insulators, and from the point of view of a power-supply company are exceedingly well insulated. The leakage currents are small and the insulators are designed to prevent any serious breakdown of the lines themselves. But whilst the loss of a few watts of power over the line insulators is of little consequence to the power-supply companies, it may be of the most serious onsequence to the reception of wireless signals. A new line with perfectly clean insulators in a perfectly dry atmosphere would cause little or no wireless interference, but as soon as the insulators become dirty, or the surface insulation tends to crack, flashover or erratic leakage at once becomes a possibility, whilst under damp conditions so-called silent discharges and corona effects become obvious. These all tend to produce electrical oscillations in the overhead lines themselves, and these lines behave like enormous aerials. Since a telegraph station may be receiving field strengths of the order of one microvolt per metre or less, the oscillations travelling along the power lines need to be of only very small amplitude to produce fields of the same order of magnitude, and a faulty insulator several miles from a receiving station may cause serious interference if the line itself runs close to the receiving aerials. No real safeguard against this type of interference is at present known, except that of burying the high-tension lines below the ground for a radius of the order of miles from the receiving station. Power companies have, however, recognized the risks which may arise of interference from their lines, and have been willing to help in the avoidance of these by burying portions of line and by super-insulating lines which come within a radius of several miles of main receiving stations.

The increased use of electrification in everyday life is tending to increase the background of noise interference at all receiving stations and most particularly at those receiving stations used by the general public for broadcast reception. Small motors, neon signs, X-ray apparatus, violet-ray apparatus, traffic lights, etc., all generate such interference, and since they are connected to the supply mains serving large areas this interference can be propagated to great distances from its actual source. It can be reduced to reasonable proportions by fitting suitable interference stoppers between the apparatus and the mains. The same applies to interference caused by tramcars and trolley-buses. Filters for the trolley circuits are, of course, relatively expensive in view of the current which has to be carried by them, and for reasonable sizes the amount of interference suppression which can be attained in practice is not so great as could be desired.

In the case of reception of wireless signals on board ships, all the usual sources of interference ashore are encountered, but with the disadvantages that they are much more concentrated, since a ship carries most of the normal facilities of ordinary life for a large number of men in a comparatively small space. In addition to the normal types of interference, a further and serious type arises owing to the vibration of stays and halyards, and to the fact that these may come in contact with one another or with earthed metal structures. It is necessary to break up the stays into comparatively short lengths by means of insulators, and to take such precautions as are possible to prevent them from accidentally rubbing together.

It has been possible to refer only very briefly to some of the major problems involved in wireless communication, and to indicate some of the factors which impose limitations on the reception of wireless signals. The science of propagation of electromagnetic waves through the upper atmosphere is, as yet, not fully developed, and investigation of the problems is exceedingly difficult. Whilst the communication engineer desires to know the effects of the upper atmosphere on the waves, and what, if anything, can be done to control and utilize these effects, the pure scientist sees in the waves a tool by means of which the upper atmosphere may be investigated, and already wireless has led to a much fuller understanding of the conditions in the space immediately surrounding the earth. Increase in knowledge of the properties of the ionized layers must lead to better wireless communication, for, although the constitution and properties of the medium are beyond control, with knowledge will come the ability to use them to greater advantage. "Man-made static" and mutual interference of stations can be largely overcome by research and by co-operation and tolerance amongst the services involved. The ultimate limits to wireless communication therefore appear to reside in the medium through which the waves must be propagated, and perhaps finally in the constitution of matter itself.

DUNDEE SUB-CENTRE: CHAIRMAN'S ADDRESS

By ALLAN GRANT, B.Sc., Associate Member.

"ELECTRICITY SUPPLY, WITH SOME REMARKS ON THE POSITION IN SCOTLAND"

(ABSTRACT *of Address delivered at* DUNDEE, *14th October*, 1937.)

Electricity is often merely regarded as a convenient form of light, heat, and power, in competition with older methods of achieving the same results, whereas availability of supply over wide areas at a cheap rate cannot help becoming a most important factor in providing such desirable sociological effects as improved conditions in industry, agriculture, and health, by fulfilling existing wants more efficiently and creating new ones. Consequently, it behoves the supply engineer to note and study the trend of modern developments in social and industrial ideas beyond the strict boundaries of his own sphere.

LOCATION OF INDUSTRY

Arising out of the debris of the economic convulsions of 1931–33 no one can fail to detect a new vitality and disposition to adopt the scientific method of impartial investigation into all social and economic problems. Whether it be the development of a social consciousness or merely the desire for economic and social stability begotten of a fear of foreign political ideas it is difficult to assess, but public opinion refuses to accept a position where parts of the country show every sign of prosperity whilst others languish in uncertainty and depression. We in this locality and in the Highlands have every reason to welcome such a trend of thought.

The factors which influence the promotion of an industrial undertaking are naturally those of availability of labour, cost of transport of incoming raw material and of the finished product, availability of power, and local rates. Public opinion rightly still supports the view that considerations of economic efficiency are of primary importance, but—here is where the modern tendency comes in—it also maintains that where costs do not prove conclusively the benefit of a particular locality the influence of some responsible regional body should have effect, whose objectives would be somewhat as follows:—

(*a*) To obtain a variety of industries in a given area so as to avoid wholesale distress due to a slump in any particular industry. It is interesting to note that a Royal Commission has now been set up to study the whole question of controlling the drift of industrial population.

(*b*) To stop the present crowding into already overburdened areas, notably the Metropolitan area.

(*c*) To obtain the right use of rural areas.

(*d*) Prevention of overlapping of local public services. For instance, marked economies could be obtained by planning the health services on a regional basis.

(*e*) Location of vital industries with regard to air attack. Have we in Scotland made enough of this point?

The manner in which these desirable conditions may be achieved would appear to be somewhat as follows:—

(*a*) *Propaganda.*

Each area should stress, through advertising and personal propaganda by its influential members, the advantages of that particular area. In this the electricity supply industry should take an active and important part, as, no matter what branch of activity is conducted, a cheap and abundant supply of electricity is essential.

(*b*) *Social.*

Local amenities must be improved. Given the usual services of electricity, transport, water, and drainage, the mass of people would prefer to spend their lives in the pleasant surroundings of a small, well-planned community. But, in addition, there must be facilities for housing, education, health services, recreation, and entertainment, in all of which electricity is an essential ingredient.

(*c*) *Financial.*

For specified areas the Government should provide capital at low rates of interest for industries which make use of some prominent local characteristic. The local authorities should grant rebates or exemption from local rates on such new industries. Also there should be national assistance for new roads, trading estates, water schemes, etc.

AGRICULTURE

It will be readily granted that a cheap and abundant supply of electricity is as important to the farmer as to the manufacturer, and will be more so as that industry becomes more and more mechanized. In my opinion the industry is in urgent need of the adoption of industrial methods and organization. Apart from the economic aspect there are other, wider, considerations such as employment and social conditions.

It has been said that a mechanized agricultural industry, such as the supply engineer hopes for, is not likely to result in a large-scale transfer of urban workers to the land which can only be a meagre success at its best, and from national defence considerations it is desirable that the land should be worked with the least man-power and not the most.

The mechanization of industry resulted in a higher standard of living for the urban worker, and it may be that a prosperous mechanized agricultural industry will perform the same service for the rural worker, i.e. higher earnings all round and a closer approach to urban conditions as regards housing, holidays, and amenities.

To one engaged in dealing with farm supplies, taking a case fresh in my mind and one which is only too typical, it seems absurd to have two farms within one mile of each other for which each farmer requires a supply sufficient for a 20-h.p. motor which will consume no more than 1 000 units per annum. This necessitates separate 3-phase tappings and transformers of 25 kVA capacity, whereas the rest of the domestic load would not require more than, say, 10 kVA. Again, in the case of most farm supplies there will be usually four cottages some 400 yards from the farms, calling for another £100 of capital expenditure on the part of either the undertaker or the farmer. So the farm labourer is more than likely to be left in the dark. At the other end of the scale we have groups of small holdings so small that none of them can justify the use of machinery and from whence the revenue/capital ratio cannot reach the figure required by economic considerations.

In consequence of the foregoing, the supply engineer desiring to be constructive cannot fail to be attracted by the suggestions put forward by Prof. J. A. S. Watson in his address to the British Association at Aberdeen in 1934; this constitutes the supply engineer's reply to his agricultural critics. Prof. Watson concluded his address as follows:—

"I well know that the whole idea of 'factory farming'—the growth of machinery and the specialization of labour—is repugnant to many people. The variety of occupations on the one-man mixed farm, the pride of individual ownership and so forth, are held to compensate for unconscionable hours of labour and small returns. But I have never been able to see that inhuman personal relationships need necessarily go with specialized occupations, short hours, and high wages. Indeed I believe that, on the factory farm, it is possible to cultivate a team spirit which is essentially a finer thing than the rather narrow independence of the smallholder. In any case, the greatest obstacles to a richer and fuller country life have always been poverty and lack of leisure. If we can remove these obstacles we shall have done much."

Given organizations such as these, with concentrations of power requirements at more or less industrial load factors and with the workmen dwelling in small communities, the supply engineer's problem would be simplified and with improved real wages for the agricultural worker that blessed expression "cheap and abundant supply" might become a reality to him.

TRANSPORT

Whilst it is outside the scope of this Address to discuss railway electrification, I would remind you of the "Report of the Committee on Main Line Electrification (1931)."

The depression and political uncertainty which followed the issue of the Report were of course sufficient to cause the subject to be left on the table. However, with the emergence of the country into what looks like a new era, the congestion of our roads and the ultimate completion of the rearmament programme, it would appear that favourable conditions will again arise, with incalculable benefits to the electrical industry in all its aspects.

In considering the above-mentioned subjects of location of industry and agriculture, any reorganization on the proposed lines would be incomplete without cheap and rapid transport. This is again too large a subject to digress upon here, but it occurs to me that the transport industry should consider some kind of two-part rate.

ELECTRICITY SUPPLY NOW A PROBLEM IN DISTRIBUTION

There is, in my opinion, little doubt that in a few years' time we shall come to compare pre- and post-depression conceptions of social and economic ideas in the same way as we now speak of pre- and post-war affairs. We shall come to regard the depression as the dividing line between the individual and local, as opposed to the national, angle of approach to problems of human well-being. In the various spheres, touching almost every aspect of our daily life, in which Government control of some kind has been introduced, it will be observed that the underlying principle involved is that the ordinary parochial outlook is not wide enough for the well-being of the nation.

In view of this new conception of organized planning or Government interference—according to the way in which it affects us as individuals—it is inevitable that the question of such an essential service as electricity supply should receive its quantum of attention. Given that a new conception of electricity distribution will take place, it is profitable to note those items of detail to which the supply engineer (having put his power house in order) will now require to give his attention.

Costing

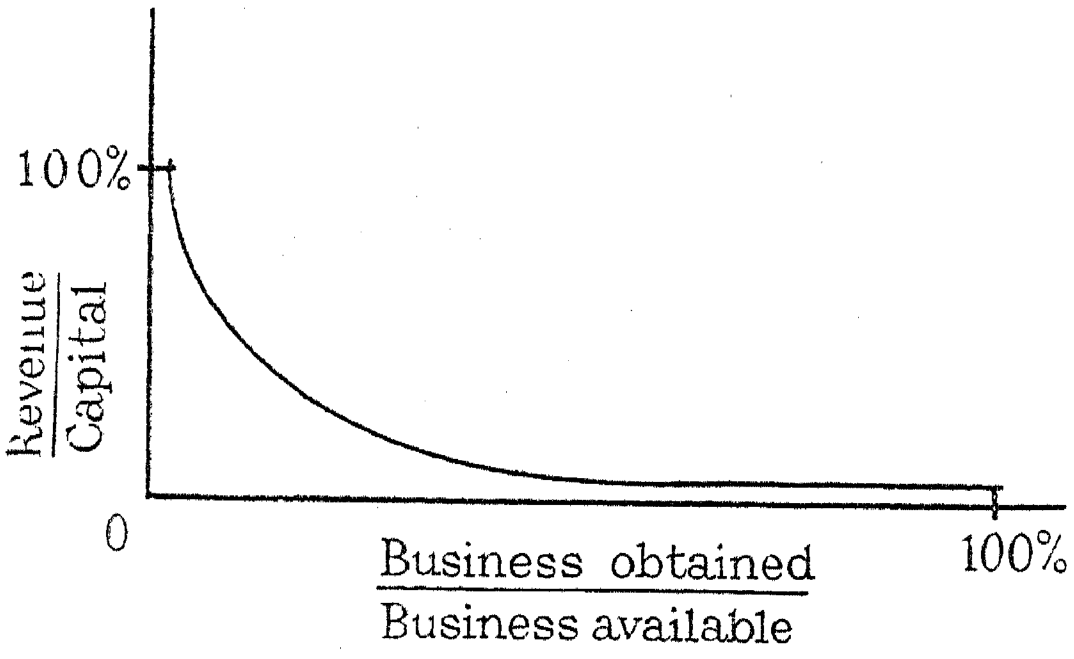
It is now accepted that the supply engineer's duty extends beyond narrow economic conceptions of merely earning a profit. Taking a narrow view, it is quite possible to build up a supply undertaking of sound financial strength by selling a few units at a high price. However, the modern conception involves a wide public-service view, requiring the engineer to measure his efficiency by the number of units sold per £ of distribution capital. In plain language, his duty is to give his consumers the maximum number of units at the lowest possible price at the earliest possible moment. It is unfortunate that no formula has yet been evolved to express distribution efficiency in this wider sense so as to permit of the comparison of one area against another. Such a development factor might be expressed somewhat as follows:—

$$\text{Development factor} = \frac{\text{Units sold per £ of distribution capital}}{(\text{Density of population}) \times (\text{Rateable value}) \times (\text{Age of undertaking})}$$

I regret I have not had the time nor the material to investigate whether such a yardstick could be evolved but nevertheless these represent the factors (with possibly others) which require to be taken into account in considering the matter.

Up to the present the method employed by the supply industry in fixing rates has been on the trial-and-error or "get as much as you can" principle. Fortunately as the original charges were of necessity high, technical advancement coupled with a gradual discernment of the market available has brought about a record of continuous reductions in such charges. This is in itself something of which to be proud. However, we must go forward actuated with a desire to accelerate development by reducing prices further, for it is recognized that we have yet a long way to go before we reach the point where further reductions will not bring increased consumption. Thus the supply engineer of the future will have to go out to attract business upon which the margin between profit and loss will come within continually narrowing limits. To deal with the more competitive business the supply engineer will require to equip himself with an accurate knowledge of his costs, of which it has been shown that those of distribution, whilst being the greater, are the least understood.

The first essential is to determine the correct allocation of both capital and running costs between transmission (33 kV and over) and distribution (11 kV and low tension). These costs are capable of further subdivision into sub-station, switchgear, transformer costs and so on. The correct allocation of distribution losses would appear to be a question which has never received the attention it deserves. Much valuable information would be obtained by the installation of metering equipments at various points on the average distribution system. There is vast scope for a statistical study of the operating costs of existing distribution systems, and it is to be hoped that with the proposed larger distribution units they will be able to afford and have the staff to make such studies. Indeed it might serve the purpose to conduct more detailed investigations in selected typical urban and rural areas. By pooling the data so obtained, sufficient information could be obtained to decide with some degree of accuracy to what price-level we can come and to what extent a zoning of prices may be necessary.



In developing rural areas it is of special importance to determine the minimum revenue/capital ratio which is compatible with sound economics. My experience suggests that if the necessary data were available the relationship between the revenue/capital ratio and percentage of available consumers obtained would be somewhat as shown in the Figure. This, I think, clearly shows the necessity of determining the critical revenue/capital ratio.

It is often advocated, usually by those outside the industry, that requests for a guaranteed revenue should be abolished. This is, however, a question of holding the balance evenly between the different classes of consumer. This would be one of the objectives of the suggested statistical survey, i.e. to determine how far uneconomic supplies may be taken on without penalizing the ordinary consumer.

Planning

Having made a detailed examination of his costs the supply engineer will then know what amount of competitive business he is likely to wrest from the coal, oil, and gas industries. The urgent need is that every supply undertaking should make a detailed survey of the electrical requirements in its area. This would be achieved by the preparation of maps noting all power users and other potential consumers, together with a card index giving such details as may be obtained as to age and condition of plant and possible developments. My experience has been that manufacturers and private individuals are genuinely desirous of promoting electrical development on principle, and are quite willing to supply the information for this purpose. Having got this information, it will be possible to determine the sizes and routes of main feeders and distributors so as to be able to meet all future requirements. The supply industry has now reached the stage where it enjoys the confidence of the investor, and, being able to raise money on very reasonable rates, it can afford to take a long and optimistic view.

Development

Taking any branch of the distributive trades, experience shows that availability of supply and low prices in themselves are not sufficient to achieve the desired results. Indeed, we now come to what is likely to be the most vital part of the distribution engineer's duty. The horse, having been brought to the water, must be *made* to drink. Shortly after the War this point was realized, and the more progressive undertakings made a start by engaging a few canvassers, sending out a few circulars, and even advertising occasionally in the Press. However, it soon became apparent that the barrier to real progress in the domestic field was that, whilst they could afford to pay for electricity consumed, the millions to whom the appeal was addressed had not the capital resources to acquire the necessary current-consuming devices. Indeed, it is interesting to note that statistics show that over 93 % of the population of this country own less than £1 000 of capital each. Consequently, the hire and hire-purchase of appliances has become the vogue. This has achieved marked results in accelerating development. However, I suggest that the next step would be to wire and equip the small consumers' houses more or less free of cost. At any rate there is again room for a detailed investigation as to whether the increase in revenue would not justify such a course. For example, take the case of a cooker only. If an £8 cooker were installed free we might expect an increase in consumption of 1 500 units per annum, with the results given in Table 1. Taking a sinking-fund repayment of the cooker at 4 % over 10 years, the cost per cooking unit sold would only be 0·107d. This is not a big proportion of the average price per unit sold for lighting, heating, and cooking, of 2·28d. for 1933–34. Upon a properly designed network, the sale of these units would be accomplished without additional capital expenditure beyond that of the cooker.

Like the manufacturer of any goods of national appeal, the supply engineer must study his market. That is, he must be conversant with the conditions of local trade, which differ in various parts of the country. To illustrate this principle—in the Highland areas it is useless to try to induce the local bakers to go in for large bread-baking ovens. It is found more profitable to sell wrapped bread made on a large scale in Glasgow and Dundee and delivered daily in these districts by motor van, the range of which is astonishing. On the other hand, the same baker can profitably bake small cakes, scones, etc., for which purpose the small pastry oven and hot-plate are decidedly suitable.

The development engineer will await with interest the results of the Government's investigation into the cost-of-living figure. From these, he will be able to note how much the low-income group can afford, or is willing to pay, for light and heat. He can then determine whether or not electricity can perform these services within that figure. If he can, and I am confident it can be done, the success of the supply industry is assured.

Table 1

	Figures for 1933–34	With free cooker
Units per £ of distribution capital	41·13	63·0
Units per consumer	1 877	3 377
Distribution capital per consumer	£45·64	£53·64

Public Relations

The supply engineer of the future must make his aims, objectives, and even difficulties, more widely known. The large undertaking of the future will have a public relation officer whose duty it will be to keep the Press informed of the undertaking's activities. My belief is that simple little articles in the Press from time to time would greatly increase the goodwill aspect of undertaker-consumer relationship. From the Press point of view electrical news is of definite service to its readers. In view of the advertising revenue derived from the electrical industry there is no doubt that the Press would co-operate. For instance, we all know of the consumer who waits until his house is completely wired and then expects the next day to get a supply of electricity like a pound of tea. Or, again, the consumer on a flat rate who suddenly starts to use a fire off his lighting circuit without changing over to the 2-part rate. Chatty articles in the Press, informing the non-consumer how to go about getting a supply and, having got it, how to use it intelligently, would do much to prevent misunderstanding.

These examples, which are only two of many, may seem childish, but my experience over 14 years in dealing with small consumers shows how ignorant the public is regarding such apparently obvious matters. Only too often can it be noted that Press publicity by large undertakers consists of highly technical descriptions of generating stations and main transmission systems, rather than the homely information indicated above.

Large-Scale Organization

With the introduction of large operating units, the supply engineer will require to make a study of large-scale organization in its various aspects, such as:—

(*a*) How far should control be centralized? The experiment in Post Office regionalization will be watched with keen interest by the supply engineer. He could also learn much from the organization employed by the large distributors of motor spirit.

(*b*) Location of stores, and central buying.

(*c*) Transport—Hiring versus a private fleet—Evolving special types of lorry.

(*d*) Desirability of staff conferences to co-ordinate work of operation, constructional, wayleaves, sales and accounts departments.

(*e*) Staff relationships.

(*f*) Letting constructional work out to contract rather than by direct labour.

(*g*) Research and pooling of data. Scientific technique is now sufficiently far advanced to permit of a much wider standardization of the more elementary articles of distribution equipment. There are, at the moment, many designs of gear for achieving the same end. There is clearly need of a central testing department for the whole industry. This department would determine the best design or, better still, get out its own designs for general application throughout the whole country. Such a scheme does not by any means involve the sterilization of new ideas. We are all acquainted with the "series" system in the motor-car industry which has given us a very superior article at a record low price.

Those of us who are engaged in negotiating new business are often involved in much laborious calculation in endeavouring to prove the benefit of the application of the electrical method to some special problem. Taking the country as a whole, this problem, whatever it may be, will crop up in numerous cases. There should, therefore, be a circulation of essential data between undertakers in different areas through some central clearing house.

In addition to research into its own technical problems the supply industry should take an active part in conducting or contributing to experiments which are likely to involve the consumption of electricity.

Relationship with the Gas Industry

Suggestions have been made, emanating from gas interests, that there are spheres of usefulness for both electricity and gas, with the inference, presumably, that the electricity supply industry should be content with the lighting and small domestic appliance load, leaving gas with the heating and cooking load. Both agencies are obviously competing for the same load, in consequence of which no such "conspiracy" is possible. The lamp- and candle-maker received no such quarter at the hands of the then youthful gas industry. The position is, that if a planned, orderly retreat of the gas industry cannot be arranged, it must be left to the free play of economic forces to decide the issue.

The annual sale of gas to 10 million consumers is at present of the order of 1 400 million therms, which, assuming an efficiency of utilization of 20 %, is equivalent to 8 200 million units of electricity. Truly there is plenty of scope for the supply industry. The question is really part of the wider problem of evolving a national fuel policy.

SCOTLAND

Whilst the foregoing remarks are generally applicable to Scotland, there can be no question that here we have a country with dense segregations of population and also a disproportionate area of the most sparsely populated country in the United Kingdom, thus presenting a problem very different from that in England. Yet, as Table 2 shows, the charges for electricity in Scotland compare favourably with those for England and Wales.

Whatever may be our views as to the best type of ownership, it speaks well for private enterprise, so far as vast areas of rural Scotland are concerned, that so much has been achieved in such a short time upon such a boldly conceived scheme, national in character. By this means sparsely populated areas now enjoy a supply of electricity on terms comparing favourably with those in more densely populated areas. It is doubtful whether the local authorities of these areas would ever have evolved sufficient breadth of view or unanimity of opinion to have taken the commercial risk of performing this service.

Table 2

(Excluding Bulk Supplies and Inter-Undertaking Sales)

	England and Wales				Scotland			
	Units sold (millions)	Revenue (£ millions)	Percentage of total revenue	Average revenue per unit sold, d.	Units sold (millions)	Revenue (£ millions)	Percentage of total revenue	Average revenue per unit sold, d.
Lighting, heating, and cooking	5 027·9	40·95	63·1	1·955	476·8	3·12	56·0	1·568
Power	7 293·5	20·50	31·5	0·675	956·5	2·16	38·8	0·542
Public lighting	236·7	1·17	1·8	1·185	34·1	0·15	2·7	1·054
Traction	980·1	2·37	3·6	0·581	43·8	0·14	2·5	0·767
Total	13 538·2	64·99	100·0	1·148	1 511·2	5·57	100·0	0·885
Power (less Lochaber Power Co.) ..					754·1	2·08	37·4	0·663
Total (less Lochaber Power Co.) ..					1308·8	5·49	—	1·007

Much appears in the Press from time to time about the lack of attention given by the central Government to Scottish economic conditions. An attempt is being made to rectify this state of affairs by the appointment of an Economic Committee by the Scottish Development Council. This committee has appointed sub-committees dealing with such subjects as industrial estates, travel, finance of new industries, special areas, gas supplies, and the Highlands. From the deliberations of these sub-committees it is hoped that some constructive proposals will emerge. It is obvious that the question of electricity supply is bound to enter into these discussions and I therefore suggest that the supply industry should be represented on that body so that it may be better informed just how far electricity can assist its aims and objects. For example, in connection with the West of Scotland gas grid proposals, could not consideration be given to the use of surplus blast-furnace gas in the generation of electricity ?

It is perhaps not generally known that the Scottish Development Council recently took premises in the Strand, London, described by the Press as Scotland's shop window. I would suggest that the Scottish supply industry sees that this point of contact with the Metropolis is adequately supplied with all necessary information on electricity matters in Scotland, including lists of works at present lying empty but suitable for light industries.

Highlands

Before concluding I should like to touch upon the problem of the Highlands, which incidentally cover one-fifth of the area of Great Britain. Much is made of the depopulation of these parts, with the consequent decay of the crofting system. Various suggestions of bolstering up this method of existence have been made with a singular disregard of economic facts. The competition of more favourably placed producers has taken away whatever markets may have existed for farm produce, and the steam trawler has caught the market from the crofter's small boat. I submit that the crofting system as an economic unit belongs to the age of the bow and arrow. A supply of electricity could not be given upon an economic basis without assistance, and would not even then stay the rot.

Any approach to the problem of retaining the Highland population must be directed to the attraction of hard cash from outside. The Highlands have a few features of a special nature which should be cultivated to its advantage and to the advantage of the country as a whole.

Tourist Industry.

The introduction of the cheap motor-car, coupled with large Government grants for road-making, at once places a valuable opportunity in the hand of the Highlander to share in the prosperity which at present exists in the industrial areas. There is immense scope for modern up-to-date hotels charging moderate prices. As our manufacturers have proved, there is big money to be made by appealing to the masses. The electricity supply industry can here play and does play an important part by offering cheap rates and hiring-out various appliances. The hotel load in the Highlands possesses the very advantageous characteristic of having its annual peak in September. Much might be done to attempt to start the tourist season earlier, as the Highland scenery in May and June is just as attractive as in the later sporting season.

Agriculture.

Although, as I have indicated, the small-holding does not in my opinion offer sufficient scope for the young and progressive agriculturist, there is room for a few small-holdings round the tourist centres to supply fresh vegetables, poultry, etc., which would provide sufficient revenue for the farmer-crofter who is attached to the land as a " way of life " rather than as a profit-earning enterprise. Here again electricity can give him amenities, which would be impossible on his croft. Indeed, the poultry-farm load can be a valuable source of revenue to the supply industry.

Again, due to the notoriously unreliable weather of these regions there is every indication that the introduction of grass-drying plant would form a profitable method of overcoming a natural difficulty. The finished product of the grass-drying plant is said to be far superior to hay as a feeding stuff and commands a good price in the market. The cost of these plants is rather beyond the scope of the individual farmer, but a very successful industry could be built up by a commercial company having such plants at strategic points, collecting grass from growers within a certain radius. This type of plant worked on this system offers a good load factor and is used in summer months only.

Water Power.

The importance of water power is illustrated in Table 3. Suggestions, to my mind fallacious, have been put forward that, rather than have large hydro schemes, each glen should possess its own small hydro station sufficient for local requirements only. So far as my experience goes, such schemes would be uneconomic from the point of view of capital and management charges and would not avoid some kind of distribution system. Indeed, I have not been impressed with the private-house hydro schemes with which I have come into contact from the point of view of actual service rendered. No ordinary consumer would put up with the type of service obtained from some of them. The laird of an isolated property would perform a much greater public service by expending a less capital sum in assisting the supply undertaker to extend his h.t. lines up the glen. By doing so he would obtain a more satisfactory service, and a supply would be within reach of the small farms *en route*, which in themselves could never produce the revenue to justify the extension and would have little hope of obtaining a supply from a private hydro plant.

It is to be hoped that the future will see full use made of whatever water power is available in the Highlands. The report of the Minister of Defence is now ready, and a Government announcement will shortly be made on the question of manufacturing calcium carbide in this country. It is understood in well-informed circles that the Committee will recommend that it should become a British industry; at the moment the bulk of the supply comes from Norway.

Whilst strong claims have been put forward for the establishment of the industry in South Wales, it will be a bitter disappointment for those who have the welfare of the Highland population at heart if such a scheme is not located in that region. With power from a hydro scheme the costs are known for all time; but if such an industry is dependent on coal, what guarantee is there that its supplies of fuel will continue at an economic figure?

Table 3

TYPE OF GENERATING PLANT

Type	England and Wales		Scotland	
	Total capacity, kW	Percentage of total	Total capacity, kW	Percentage of total
Steam and others	7 255 605	99·378	601 710	75·4
Water	47 475	0·622	197 080	24·6
Total ..	7 301 080	100	798 790	100

CONCLUSION

In this Address I have, as it were, surveyed our industry from the heights of the Grampians and pointed out some of the peaks in the foreground, but away in the hazy distance we can discern other, larger peaks which will have to be scaled some day. In other parts of the world we see vast potential water-power resources capable of being coupled with large irrigation schemes, and other continents with vaster coal resources, so that an eventual shift of population seems inevitable. In the middle distance we are about to be faced with a rapidly falling population, leaving what may be a graveyard of capital works in the form of houses, roads, etc. the economic problems of which have not yet been hinted at. In the meantime we in the electricity supply industry are to be charged with the task of bringing about the " electrical age " and, whilst there may be no glittering prizes, we shall not be found wanting in energy and vision.

SHEFFIELD SUB-CENTRE: CHAIRMAN'S ADDRESS

By W. FORDHAM COOPER, B.Sc., Member.

"LOAD DIVERSITY ON TRACTION, POWER, AND DOMESTIC SUPPLIES"

(ABSTRACT *of Address delivered at* SHEFFIELD, 20*th October*, 1937.)

It is usual for a Chairman to deal in his Address either with some aspect of his daily professional work or some subject of general interest. As I have recently dealt with the first, I have selected a subject which has lately received considerable attention in the *Journal* and in the technical Press, and to the discussion of which members of this Centre have made a number of useful contributions. I propose, therefore, to describe briefly my own investigations during the years 1925–30, but to deal with the later investigations first as they were of more immediate practical importance.

Table 1

Feeder No.	1	2	3	4	5	6	7	8
Estimated max. demand, kW . .	520	420	650	320	320	655	230	650
Number of measurements	4	4	5	8	8	1	1	1
Max. demand, kW	593	420	653	341	291	617	200	610
Mean max. demand, kW	549	330	637	296	270			

In 1929 it became necessary to build a number of new traction substations for supplying suburban tramways, and the first consideration was to estimate the load which they would have to carry in normal and abnormal circumstances, e.g. ordinary week-day load and during Christmas shopping or times of big football matches. For main-line electrification it is possible and usual to make elaborate time schedules with speeds, gradients, etc., and to predict the load at any particular moment, but with tramways the load on a section of track varies from minute to minute, depending primarily on the degrees of traffic congestion. However, it was possible to get the average schedules (headways) from the Traffic Department and to estimate with fair accuracy the average ampere-hours per mile for different types of car under varying conditions. From these data the following equation was evolved:—

Maximum demand (as measured by an integrating demand-indicator) = (Cars per hour) × (Average units per mile) × (Miles of track) . . . . (1)

The figures were checked by tests on an isolated length of track and by comparing estimates made on this basis with the actual recorded demands at a number of existing substations. The accuracy of the method was found to be quite sufficient, as shown by Table 1.

The load thus measured is the average load for 15 minutes during the peak, but a tramway load varies from second to second, and the instantaneous peaks are very considerably larger than the maximum demand indicated. This has an important bearing on the rating and performance of plant. For example, a steel rectifier is usually guaranteed to withstand 100 % overload for 2 minutes, and the circuit-breakers should be set to ensure that excessive peaks due, for example, to bunching of cars are prevented. A number of recorder charts of such loads were taken, but an instrument was not available which would "write" sufficiently quickly, and it is certain that the peaks were not accurately recorded and a very much greater chart speed would be necessary for convenient analysis. However, I have had part of a chart enlarged optically and analysed, and I have plotted the frequency curve in Fig. 1. Such a curve is said to be unimodal, i.e. it has only one maximum or mode, which is generally at slightly less than the average

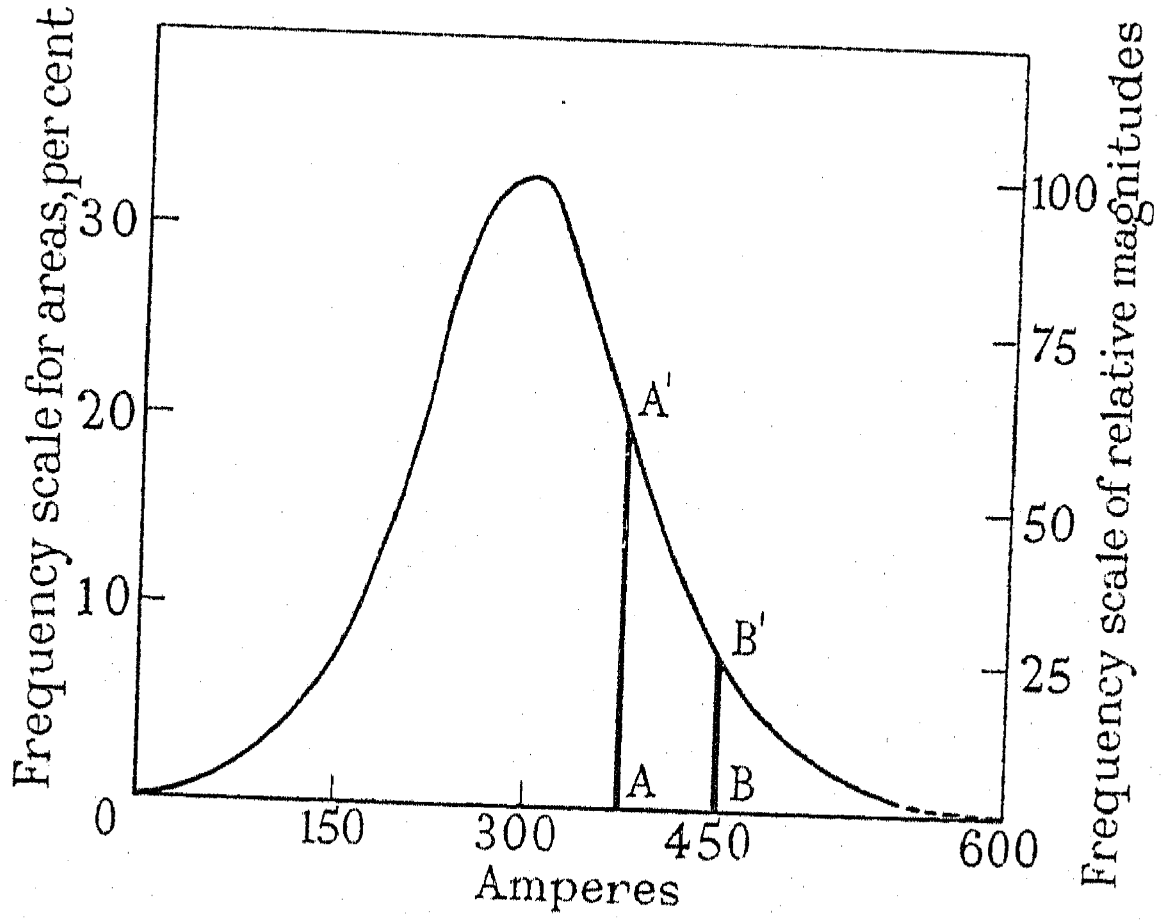


Fig. 1.—Analysis of recorder chart.
Due to the sluggishness of the recorder the peaks are missed and the curve is generally too narrow, i.e. the standard deviation is too small.

or mean current. The total time during which the current was between any two values such as A and B is represented by the area AA′B′B. Thus if the scale is so chosen that the total area is, say, 100, then this area is the percentage time during which the current was between these two values. In drawing such curves, however, I have found it more convenient to make the maximum ordinate 100, so that the relative importance of different parts of the curve can be seen easily.

Statisticians have always attached particular importance to what is called the " standard deviation " σ of such a curve, which is in effect the radius of gyration of the area of the curve about the average value, and have studied this measure very closely. This is very fortunate for electrical engineers since

$$I^2 = \bar{\imath}^2 + \sigma^2 . \qquad (2)$$

where I is the r.m.s. value of the current and $\bar{\imath}$ is the average value. Any method, therefore, which will help to measure σ is a method for estimating the copper losses.

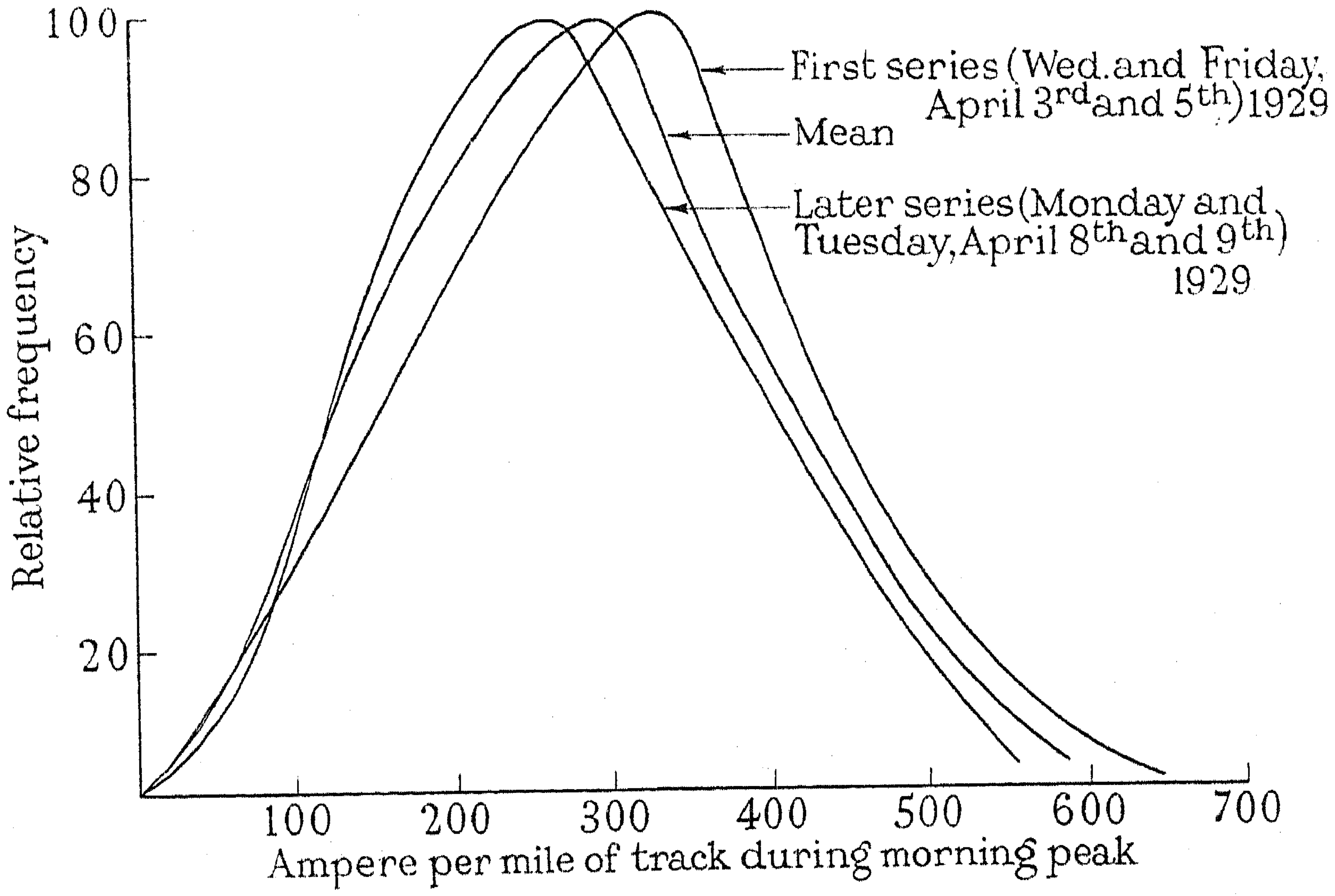


Fig. 2

The load frequency curve for a particular supply was carefully derived, and approximate curves were obtained for a number of other supplies. As mentioned above, however, the chart recorders available were not sufficiently accurate or convenient and a simple method of sampling was adopted. A switchboard attendant took spot readings of the ammeter every 15 or 30 seconds during the period of maximum load. For the principal curve approximately 500 readings on 2 days were taken. An alternative method—considered but rejected because of the cost—was the use of a " tapping " recorder which operates automatically on the same principle. As has been pointed out by Lexis, Keynes, and others, the use of statistical measures is not justified unless the distribution curves are stable. That this condition is at any rate approximately fulfilled is seen from the curves for different days shown in Fig. 2. This point is of great importance and should always be investigated. For the supplies studied it was found that $\epsilon^2 = \sigma^2/\bar{\imath}^2$ varied between 0·15 and 0·2.

In making these studies I was interested not so much in the efficiency of the plant as such as in the short-time rating. The rectifiers used were guaranteed to carry 25 % overload for 2 hours, 50 % for 15 minutes, and 100 % for 2 minutes.* The losses in the steel tubes of the rectifiers are proportional to the current, and therefore the maximum demand as estimated by equation (1), which gives the average value, is the appropriate figure to use. In the transformers, however, the losses are proportional to the current squared, and the appropriate load to consider is the r.m.s. current discussed above.

Both rectifiers and rotary convertors are very sensitive to excessive momentary peaks, and frequently have to be protected from them by high-speed circuit-breakers on heavily loaded sections; the traffic density on some sections was very heavy indeed. It was necessary, therefore, to set the circuit-breakers to interrupt such current-rushes, the breakers being designed to reclose automatically after a short interval; if they failed to stay in on the second reclosing they remained open. The investigations showed that, for the lines studied, peaks of 2 to $2\frac{1}{2}$ times the mean recorded demands regularly recurred, and the breakers should therefore be set at nearly 3 times the recorded demand if only abnormal peaks were to be excluded. This obviously sets a minimum value to the instantaneous peaks which rectifiers or convertors must withstand. The rectifiers could take isolated peaks of 200 % for 5 seconds (the British Standard Specification allows 100 % for 15 sec. in the case of a rotary convertor). It is seen that, provided the turns are properly braced against short-circuits, the maximum demand which substation transformers can safely handle depends primarily on the r.m.s. current, while rotary convertors or rectifiers are limited primarily by their ability to deal with instantaneous peaks. Both these are best studied by the methods which I have been describing.

It may be asked whether one may predict the form of the frequency curves we have been discussing. Generally speaking, I think this would be impossible except in the simplest cases, as there are too many unknown causes of variation. In telephone work, however, Poisson's distribution $n = u^r/r!e^u$ is sometimes used to predict the number of simultaneous calls on an exchange or circuit. In the case of a load which was built up of equal "lumps" there would be some approximation to this distribution. A rolling-mill load curve is somewhat of this type, and a welding generator supplying a large number of welders would be another example. I found in the tramway problem that, by assuming that the load varied by exact multiples of the average current per car, a distribution very similar to the actual distribution was obtained. It must be emphasized, however, that such a calculation is based on an insecure foundation, and it is at best a matter of intuition whether it is likely to lead to a reasonably accurate result.

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* The appropriate British Standard Specification allows 100 % for 15 minutes for a transformer.

The investigations just described suggest that it should be possible to apply statistical theory to the connection between diversity and copper losses. To do this it is necessary to examine the effect of combining two or more frequency curves. Two elementary cases can be taken as typical:—

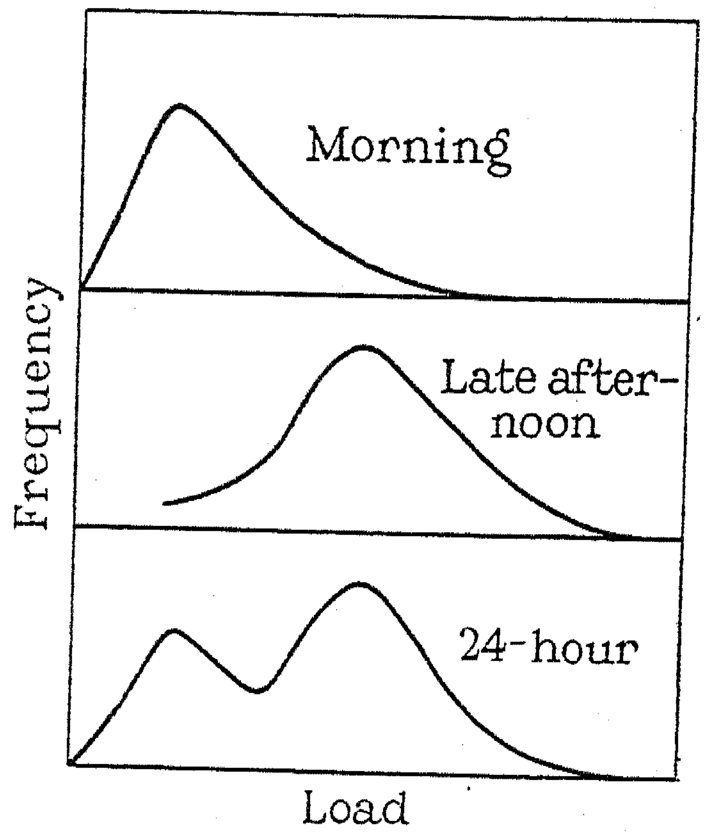

Fig. 3

(*a*) If the curves are determined at different times of the day, such as morning and evening, the effective combined distribution is obtained simply by adding the results together and readjusting the scale so that the maximum is 100 or the area unity according to the convention adopted (see Fig. 3).

(*b*) If, however, two similar loads, such as two traction routes, are fed together from the same supply, the r.m.s. total load will be less than the sum of the r.m.s. values for the individual supplies, since the momentary peaks will not coincide and we can add neither the ordinates nor the abcissae. However, the mean current as measured by an integrating demand indicator will be the sum of the means, so that

$$\bar{\imath}_0 = \bar{\imath}_1 + \bar{\imath}_2$$

but

$$\sigma_0 < (\sigma_1 + \sigma_2)$$

Statistical theory suggests that in a very great many cases a good approximation will be

$$\sigma_0 = \sqrt{(\sigma_1^2 + \sigma_2^2)}$$

and therefore when there are n loads identical in character

$$I_0^2 = n^2\bar{\imath}^2 + n\sigma^2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

These two cases (*a*) and (*b*) may be conveniently referred to as systematic and statistical diversity of supply; the former is used to advantage in forming tariffs for off-peak loads. Many practical cases, however, combine the two features, the main incidence of two classes of demand being at somewhat different times but the tails overlapping. For statistical diversity the excess of actual copper losses over those calculated from an integrating demand meter is therefore given by

$$\text{Excess (per cent)} = 100\epsilon^2/n \quad . \quad . \quad . \quad (4)$$

which gives a relation between number of consumers and losses ($\epsilon = \sigma/\bar{\imath}$). From the data obtained in the investigation of tramway loads it appeared that some such law held, but the conditions were not sufficiently stable to check it properly.

The study of peak demand is much more complex. To begin with, it is rather difficult to define suitably. In the following notes it is assumed to be the average value of the maxima recorded in a fixed period for a large number of precisely similar loads. Thus defined it will be a function of the standard deviation, and $2\frac{1}{2}\sigma$ to 3σ would usually be the order of magnitude, depending partly on the degree of asymmetry of the frequency curve. Then

$$\text{Peak load } (M) = \bar{\imath} + \alpha\sigma$$

If a number of loads coincide in time, we can combine the standard deviations for symmetrical curves as before, so that $M = \Sigma\bar{\imath} + \alpha\sqrt{(\sigma_1^2 + \sigma_2^2)}$, etc., will give a reasonable estimate of the combined demand, and for the special case of a number of exactly similar demands

$$M = n\bar{\imath} + \alpha\sigma\sqrt{n} \quad . \quad . \quad . \quad . \quad . \quad (5a)$$

while the load factor (L) is given by

$$\frac{1}{L} = 1 + \frac{\alpha\epsilon}{\sqrt{n}} \quad . \quad . \quad . \quad . \quad . \quad (5b)$$

and the load factor (F) of the losses by

$$F = L^2\left(1 + \frac{\epsilon^2}{n}\right) \quad . \quad . \quad . \quad . \quad (5c)$$

Most distribution curves, however, are not symmetrical, and a correction has to be made for small values of n. This is found empirically to be obtained by using the formula

$$M = \alpha n + \frac{\beta n}{\sqrt{(n-1)}} \quad . \quad . \quad . \quad . \quad (6)$$

This can perhaps be checked by the figures for cooker load given by the National Electric Light Association in 1926 (see Table 2).

The agreement is, in fact, so good as to throw doubt on the reliability of the data.

These results were given by me in an (unpublished) lecture early in 1926, and it is interesting to note that during the same winter O'dell* stated that an empirical formula equivalent to equation (5*a*) had long been used by telephone engineers for giving the probable number of simultaneous calls at a telephone exchange, and he suggested a theoretical basis very similar to that given above.

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* *Journal I.E.E.*, 1927, vol. 65, pp. 189 and 206.

It will be noted that this analysis of maximum demand has been limited to average values under standardized conditions. This is necessary because the toe of the distribution curve is much less certainly defined than the centre and slopes. Theory suggests that wide deviations are to be expected, and in practice we know that peak values often arise from abnormal conditions which have little bearing on the general form of the curve. There might be, say, a street accident in the case of a tramways load or an abnormally severe frost in the case of a heating load. We cannot expect the system of load analysis to allow for such matters. For this reason it is more sound to relate estimates of losses, etc., to the average load and standard deviation as above than to the maximum demand and load factor.

Table 2

n	M/n (calculated)	M/n (observed)
	kW	kW
5	1·65	1·75
10	1·33	1·36
20	1·14	1·13
40	1·04	1·00
80	0·91	0·89
150	0·86	0·86

The convenience of using the latter has, however, caused a number of people to suggest formulae of the type

$$F = aL + bL^2 \ [\text{where } (a + b) = 1]$$

Of these the following may be mentioned. In 1920 W. B. Woodhouse* suggested $\frac{1}{2}(L + L^2)$. In 1924 C. C. Garrard† gave a curve derived by P. Torchio which can be represented by $\frac{1}{3}(L + 2L^2)$, and more recently D. J. Bolton‡ has given $(0 \cdot 3L + 0 \cdot 7L^2)$. There is no clear reason why all supplies should follow one law, but I have found that a number of public supply daily, weekly, and annual load curves are in approximate agreement with the second form.

I will conclude by pointing out the relation between this work and the more recent investigations by Wedmore and Flight. In their paper* in 1935 they gave a number of distribution curves for the voltage regulation at the end of a feeder. I have previously pointed out† that this is equivalent to giving the distribution of Ix, where x is the length of "equivalent 1 sq. in. cable" and I is the current, or, with nearly the same accuracy, kW-yards of load. If the distribution of the load along a feeder could be determined it would be possible (though usually difficult) to correlate their distribution curves with those I have given. In the early lecture which I have mentioned I assumed (no doubt somewhat arbitrarily) that equation (5a) would apply to these curves, and from this I estimated first the deflection of the neutral point on a typical 3-phase 4-wire supply to a domestic area. From this again it was easy to calculate the optimum ratio of the area of the neutral to the area of the phase conductors for good voltage regulation. The basis of the calculation was perhaps somewhat insecure, but as it led to a neutral larger than the phase wires, it was clear that the very small neutrals then common were definitely of the wrong size. Thus one small nail was driven in the coffin of a bad practice.

In the above remarks I have described some of my own adventures in a very fascinating field of research. The estimates I was enabled to make, particularly in the earlier part of this Address, were on the whole better than I had expected. A final warning is necessary, however, in regard to the more speculative sections. They are, I think, of practical value chiefly because they enable one to make some estimate in matters which are so complicated that even a poor estimate is better than no estimate at all.

In conclusion I should like to thank Captain J. M. Donaldson, M.C., and the North Metropolitan Electric Power Supply Co. for permission to use some of the data in this Address.

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* *Journal I.E.E.*, 1920, vol. 59, p. 91.
† *Electrician*, 1924, vol. 92, p. 479.
‡ *World Power*, 1932, vol. 17, p. 14.

* *Journal I.E.E.*, 1935, vol. 76, p. 685.
† *Ibid.*, 1936, vol. 179, p. 52.

NORTHERN IRELAND SUB-CENTRE: CHAIRMAN'S ADDRESS

By F. H. WHYSALL, Member.

(ABSTRACT *of Address delivered at* BELFAST, *26th October*, 1937.)

First let me say how much I appreciate the honour you have conferred upon me by electing me Chairman of this Sub-Centre. That we have succeeded in establishing this Sub-Centre is a source of great gratification to me, and in this connection I feel that we owe a deep debt of gratitude to Mr. Partridge, our first Chairman, for the part he played in establishing it. It is my hope that I shall succeed in furthering the interests of The Institution in Northern Ireland in the same manner as my predecessor.

The Institution is especially interested in Ireland on account of the recent rapid development of electricity supply, the work of the Post Office, and the increase in the number of people engaged in electrical work, and gave tangible proof of its interest by choosing Ireland for the Summer Meeting in 1930. I feel sure that that visit has materially benefited those of us in Northern Ireland who are interested in The Institution.

Before the formation of the Northern Ireland Sub-Centre it was difficult to maintain interest in The Institution in Northern Ireland, owing to the fact that many found it impossible to attend meetings of the Irish Centre in Dublin. The formation of this Sub-Centre has overcome this difficulty and I feel sure that we shall be able to obtain a large increase in membership in Northern Ireland. I should be glad to see as many electrical engineers in this area as possible enrolled in some class of membership, and in this connection I feel that we should make a special effort to encourage young men, especially those who are in the student or apprenticeship class of our profession, to join The Institution. I appeal strongly to all those in positions of authority to encourage younger members of the profession to enrol under a suitable grade of membership.

It is usual for a Chairman in his Address to speak about the particular branch of the profession in which he is himself engaged. When I was Chairman of the Irish Centre in 1930 I dealt with the organization and work of a large electricity supply undertaking, with particular reference to efficiency. On this occasion I propose to review the coal position, as the generation of electricity is mainly dependent upon supplies of coal.

The coal industry is the foundation of our iron, steel, shipbuilding, and engineering trades, and indeed our whole industrial life. The value of its products is in the neighbourhood of £170 millions per annum.

The year 1913 marked the peak of the industry's prosperity. In that year 287 million tons of coal were raised and 98 million tons exported, and it is well known that the export trade rather than the home trade is the cause of most of the industry's difficulties.

Statistics show that during the year 1923 approximately 104·5 million tons of coal were exported, but in 1926 the export figure had dropped to approximately 30 million tons, and last year it was approximately 50·5 million tons. The total output of coal during last year was approximately 229 million tons.

The iron and steel trade is the largest industrial consumer of coal and it accounts for approximately 20 per cent of the total inland consumption. The demand for industrial coal and coal for public utility undertakings is steadily increasing, whereas the demand for house coal is decreasing. It is interesting to note that immediately after the War the annual consumption of house coal was approximately 40 million tons, whereas to-day it is in the neighbourhood of 36 million tons.

It is well known that there are substantial deposits of coal in Ireland, which deposits have been determined by geological survey. It is true that Ireland as a whole does not contain coal deposits comparable either in quantity or quality with those in Great Britain, but Northern Ireland does contain large deposits of good coal which, though not easily obtained, may in the future be developed and become of considerable importance. In Southern Ireland anthracite exists in fairly large quantities, and in Western Ireland coal of a semi-bituminous nature is mined to some extent.

The principal Northern Ireland coalfield is situated in County Tyrone, where there is an abundance of good-quality bituminous coal. The coal seams run in a north-easterly direction towards Coalisland, and in the north are cut off by a large up-throw fault of about 3 000 ft. This fault flanks the coalfield on the north until its effect is lost in an overlying basalt formation towards Lough Neagh. It seems fairly certain that the coal stratum continues beneath Lough Neagh and that the main mountain ranges of County Antrim form the east wall of a large basin existing in this district which may be rich in coal. Unfortunately, volcanic eruptions have so displaced and twisted the coal stratum, and basalt formations have so covered it, that at present the mining of the coal is not a commercial proposition.

The presence of coal has been determined at Carrickfergus and Ballycastle, and it would appear, therefore, that coal seams exist from the County Antrim mountains eastward, probably linking up with the Ayrshire coalfields. The extent to which these coal seams are under land in County Antrim has not been determined.

Coal mining in Northern Ireland has been carried on for many years on a small scale, but it was not until 1920 that an attempt was made to open up a large colliery at Coalisland in County Tyrone. Boring was very costly, owing to the presence of basalt rock and large boulders, but since the existence of substantial quantities of coal was proved it was decided to sink a shaft and to commence mining operations. The sinking of the first shaft was commenced in 1921. The shaft was sunk to a depth of 1 100 ft. and in this depth 12 seams of good-quality coal were encountered, varying in thickness from 4 ft. 9 in. to 9 ft. 6 in. In addition, fireclay and shales were found in abundance. It appeared at this stage that the coal-mining industry in Northern Ireland would be definitely established. When mining operations were commenced, however, it was found that the seams had been torn and twisted by volcanic upheavals and that the stratum dipped in places to an angle of 60°. In addition, great difficulties were experienced in keeping the cuttings open, owing to the nature of the fireclay stratum, large amounts of steel and timbering having to be used to support the roofs.

In all, approximately 50 000 tons of coal were raised, in addition to immense quantities of fireclay shales, and the project ended in failure.

In view of the above difficulties it is very unlikely that coal mining will be largely developed in Northern Ireland for a considerable time. Nevertheless, it should be remembered that there is a large quantity of good coal in Northern Ireland.

The coal which is being used for the generation of electricity in Northern Ireland is obtained chiefly from Ayrshire. It has a low sulphur content and, whilst not having a high calorific value, has proved satisfactory, but unfortunately, owing to the coal shortage and the suitability of this type of coal having been discovered by other undertakings, the competition for it is very keen and is affecting the price.

In common with most supply engineers I am very much concerned with the causes which are increasing the cost of coal to electricity undertakings. It has been my experience for many years to see reductions in the amount of coal used per unit generated robbed of their financial benefit to the undertaking by increases in the coal prices. I have repeatedly purchased fuel which was regarded as pit-head refuse, only to find after spending time and money on solving the problem of its commercial use that the price had been increased to a prohibitive figure.

Colliery owners try as far as possible to obtain orders for all classes of fuel output, as it is necessary for the economic working of the colliery that sales should be balanced. The development of appliances to use what was formerly considered low-grade fuel has increased the demand for this fuel so much in excess of the demand for screened large coal that this balance is now upset. Colliery owners claim that the low-grade fuel has been sold at a loss and that it has been necessary to balance this loss in the price for screened large coals. This, they say, is not possible when the demand for screened large coal falls below a certain level, and so the price of low-grade fuel is increasing. In other words, by developing electricity supply and the use of electricity for domestic purposes and industrial processes the demand for coal used for these purposes has been decreased, and the results of this decrease are reflected in the price paid for coal by electricity undertakings.

It is interesting to note in this connection that it has been suggested that electricity undertakings should use a certain proportion of screened large coal in order to counteract the decreased demand for this type of coal from other sources, and recent specifications for coal issued by some supply undertakings have made provision for this, the coal being crushed at the power station to a size suitable for use in the boilers.

Another factor which, to my mind, has tended to increase the price of coal to electricity undertakings is the increased size of the modern power station. It is more difficult to buy large quantities of coal at a low average price than to buy small quantities at a low price. The large buyer may buy some coal at a very low price, but in order to obtain all the coal necessary he is often forced to pay a much higher price for quantities in excess of a certain amount, so that in fact the rapid development of electricity supply, by increasing the demand for certain grades of fuel, is causing an increase in the price of that fuel.

The effect of recent legislation on the price of coal has also to be considered. During the year 1936 the Coal Mines Act of 1930 was amended and District Selling Schemes were co-ordinated. These coal-marketing schemes, in my opinion, have had the effect of eliminating competition between collieries and would appear at present to have resulted in fixing the source and price of coal for any electricity undertaking, and in leaving that undertaking with very little bargaining power except what can be obtained by the adoption of some alternative source, such as the use of oil fuel in boilers, Diesel engines, or water power. In recent years these alternative sources of power are being more fully utilized.

The use of oil as a substitute for coal, whilst it has many points to commend it, has two great drawbacks. All oil supplies must be sea-borne from foreign countries and, in the event of international crises, supplies of fuel might be cut off. In addition, the problem of storage of large quantities of oil presents many serious difficulties.

I am inclined to think that the development of water power should be carried out as far as practicable. Particularly is this the case in a country such as Ireland where there is practically no coal that can be mined with commercial success. Unfortunately, here we have not many large rivers, and development of water power on those existing is difficult. One of the greatest difficulties in developing water power is the cost of dealing with vested interests, and this difficulty has so far prevented the development of any hydro-electric schemes of importance in Northern Ireland.

The electrification of collieries has played a great part in making the mining of coal easier, and has tended to reduce the price of coal at the pit head. Unfortunately, most collieries have now exhausted their easily-obtained supplies of coal and are forced to cut coal from narrow seams at a great depth from ground-level and at an appreciable distance from the shaft. Thus the price of coal at the pit head has tended to remain constant rather than to decrease. Since it is not possible to build every power station at a pit head, the price paid by the electricity undertaking is often the pit-head price plus the cost of transport and merchant's profits, and in this connection the loyalty of the mine owner to the merchant is a troublesome bargaining handicap, since the mine owner refuses to offer, or allow anybody else to offer, coal except through the merchant who has once obtained an order from any source.

While I am one of those who think that in general the middleman earns his place in the scheme, I do believe that, in some instances, being tied to him may give him a larger profit than would otherwise be considered reasonable.

Even with these conditions the position would not be too bad if it were possible to purchase coal on a calorific basis, so that the engineer would be in a position to assess the cost of purchase of heat units. Unfortunately, the attitude of most mine owners to this suggestion is one of refusal, even to the extent of filling in tender values of calorific value and labelling them " approximate."

The supply engineer can to a certain extent combat the effects of increasing coal prices by improving the thermal efficiency of his generating stations, and the tendency for coal prices to increase has, I think, benefited the electricity supply industry generally by forcing engineers to direct serious attention to the question of effecting economies. Accurate checks are kept on the calorific value of all fuel purchased, and the process of combustion is kept under very close control.

I do not wish to alarm my audience unduly by this review of the trend of coal prices, but, would say rather that the trend is not altogether to be deplored. It is well known that mine owners have passed through a very difficult period, and very few people would grudge an improvement in the wages of the working miner. If coal-marketing schemes, even when they tend to increase prices slightly, can improve conditions in the mining industry and at the same time protect public utility undertakings from exploitation, I have very little fault to find with them. Mining shares have been at a discount, and practically no new mines have been opened for the last 25 years. Hence, whilst the immediate effect of controlled marketing schemes may appear evil, one hopes that out of evil may come good, and that with the improved position of the industry there may be an inducement to sink new shafts and to abandon the worst of the old collieries, thus reducing the average pit-head price of coal.

Since both the electricity-supply industry and the coal-mining industry are coming more intimately under Government control, I do not think that there is any real danger of one industry being exploited to the advantage of the other. Existing conditions, rather, are of a temporary nature to allow both industries to put their finances in an economic position.

AN ELECTRICAL METHOD OF DETERMINING CABLE-SHEATH UNIFORMITY*

By W. E. LAYCOCK, Graduate.

(Abstract *of Paper read before the* London Students' Section, *7th December,* 1936.)

INTRODUCTION

It is known that the inductance of a coil of wire decreases when a non-ferrous conducting body is in close proximity to it. This paper describes the application of the principle to the measurement of non-ferrous conducting cylinders, or sheaths, with particular reference to its use as a means of controlling the thickness of cable sheaths during their extrusion from the lead press. A method of automatic control of the lead-press heaters by the detector during sheathing operations is suggested.

The lead press used for sheathing cables cannot ensure a uniform sheath because the critical factor determining the uniformity of thickness is the temperature at different parts of the die box. A higher temperature allows a greater flow of metal (and consequently a thicker sheath) to occur at a given spot, and vice versa.

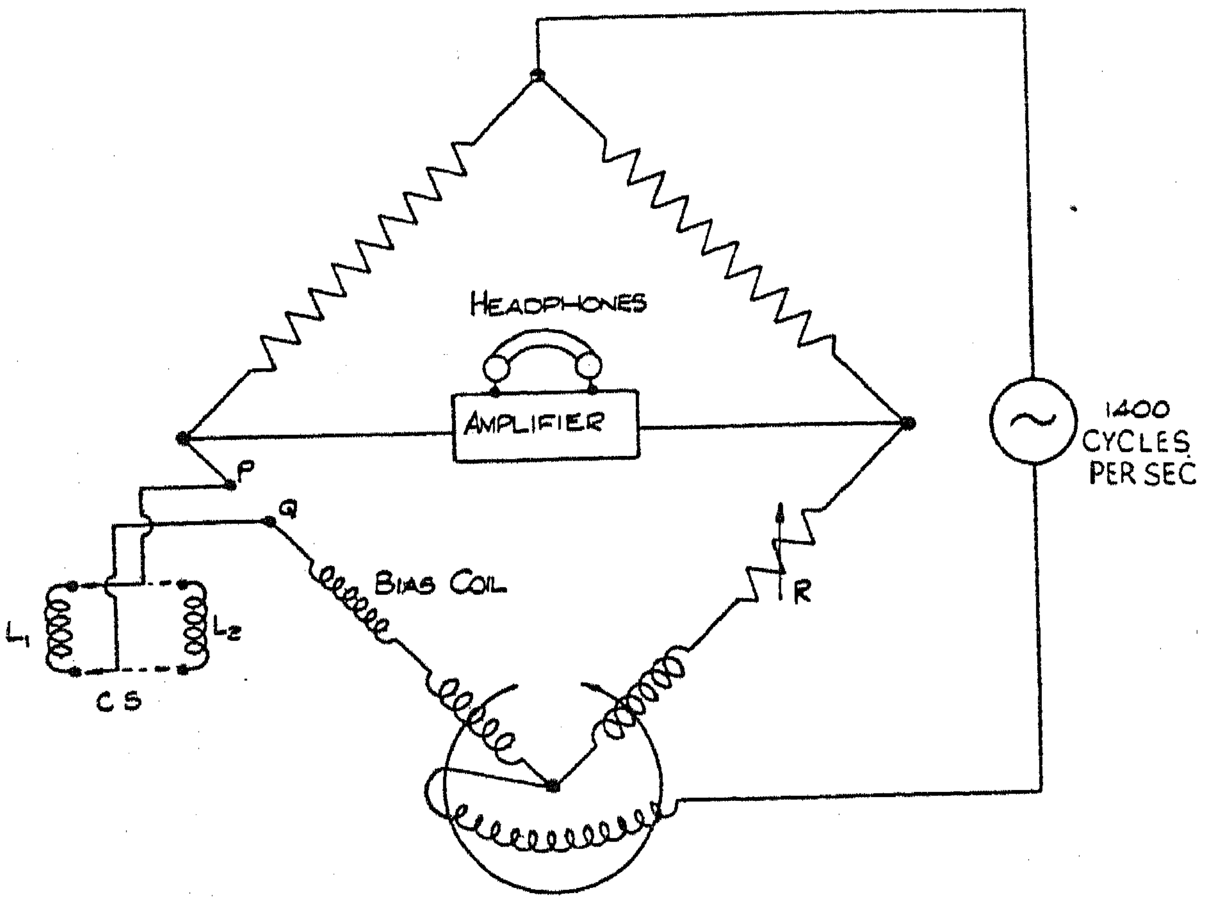

Fig. 1.—Wiring diagram for "actual" thickness measurements.

By suitable adjustment of the heaters around the die box, the temperature and hence the wall thickness at any point around the die perimeter may be controlled. It is certain, however, that this temperature varies in a haphazard manner during extrusion.

The lack of sheath uniformity has serious repercussions in the form of split and punctured sheaths on most high-voltage cables which are at present manufactured. The absence of a satisfactory method for measuring the thickness of sheaths has now become a problem requiring careful consideration.

The usual procedure is first to determine the wall thickness by means of a micrometer, and then to adjust the lead-press heaters until uniformity is obtained. In the past the only exact way to measure the sheath at any point was to remove it from the dielectric, which is obviously impracticable. An investigation was therefore opened to overcome these difficulties.

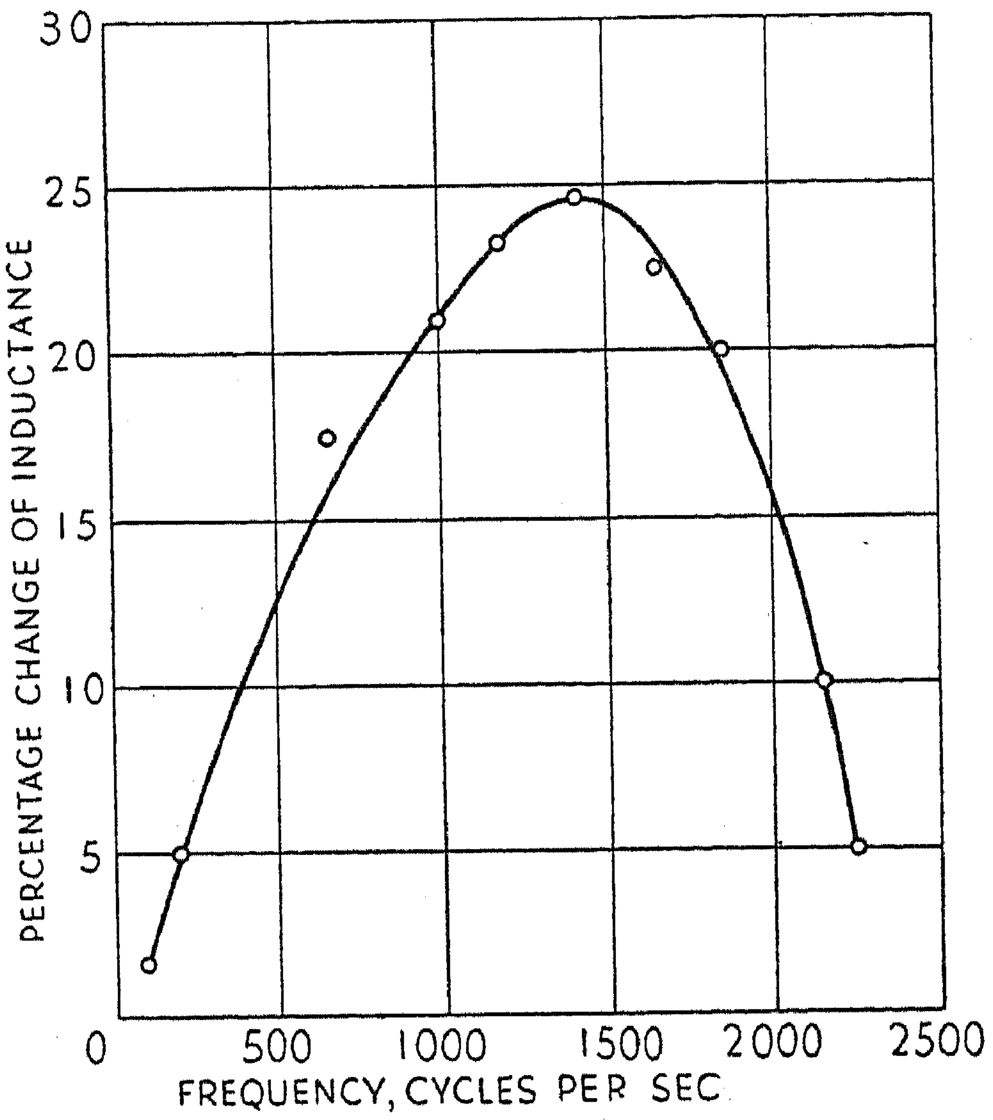

Fig. 2.—Curve showing relation between frequency and percentage change of inductance.
Sheath thickness = 150 mils.

THE EVOLUTION OF THE GAUGE: "DIRECT" METHOD

For the change-of-inductance measurements to be described herein, it was decided to use the Heaviside–Campbell equal-ratio inductometer bridge.† The unknown inductance was, in this case, in the form of a search coil.

Two coils (L_1 and L_2) were placed on opposite sides of the sheath and suitably connected into the bridge circuit as shown in Fig. 1. The degree of unbalance produced by the insertion of the sheath was employed as a measure of its actual thickness, and, this having been done for opposite sides of the sheath, the difference in thickness between the two sides was found.

It was observed that for a maximum inductance-change, together with sensitivity, there was an optimum frequency, depending upon, among other things, the

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* The original paper, of which this is an abstract, was awarded a Students' Premium by the Council.

† B. Hague: "A. C. Bridge Methods," p. 302, para. 37.

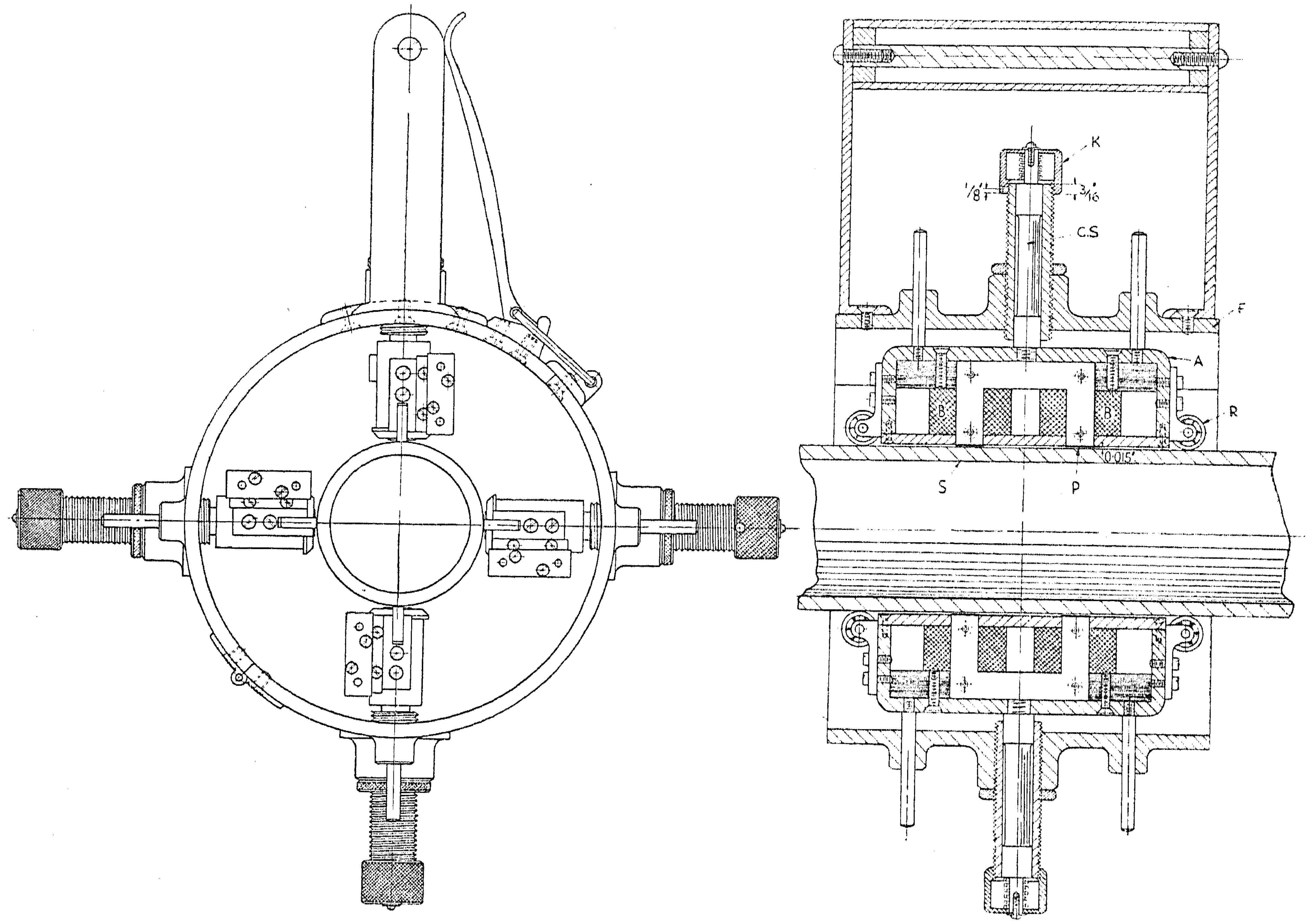

Fig. 3.—Constructional details of sheath-uniformity gauge (not to scale).

metal used. With lead, a frequency of 1 400 cycles per sec. was the best.

Fig. 2 shows a curve of frequency plotted against percentage change of inductance, obtained on a high-voltage sheath 150 mils thick. At 50 cycles per sec. the flux passed freely through the lead and little change of inductance took place; at 2 200 cycles per sec. and over, however, the flux only penetrated the skin of the sheath and it was therefore of no consequence whether the sheath was 100 or 150 mils thick, because only the outside 20 mils was effective. On the other hand, with a nominal 150-mil sheath with 20-mil variation of thickness, 1 400 cycles per sec. showed the biggest change.

IMPROVED CIRCULAR MODEL

An improved circular model was constructed, embodying four coils instead of two, thus enabling thickness measurements to be made for any quadrant around the sheath periphery. This method was found to be unsatisfactory because of its susceptibility to temperature-changes.

THE "DIFFERENTIAL" METHOD

With this method, the difference of thickness between any two parts of the sheath could be determined instead of the actual thickness on each side, as in the "direct" method. This difference of thickness is a measure of the circumferential non-uniformity of the sheath, and can be obtained for any position along the cable. The system required a slight modification to the bridge circuit. Measurements by the differential method showed the method to be practically unaffected by temperature-changes.

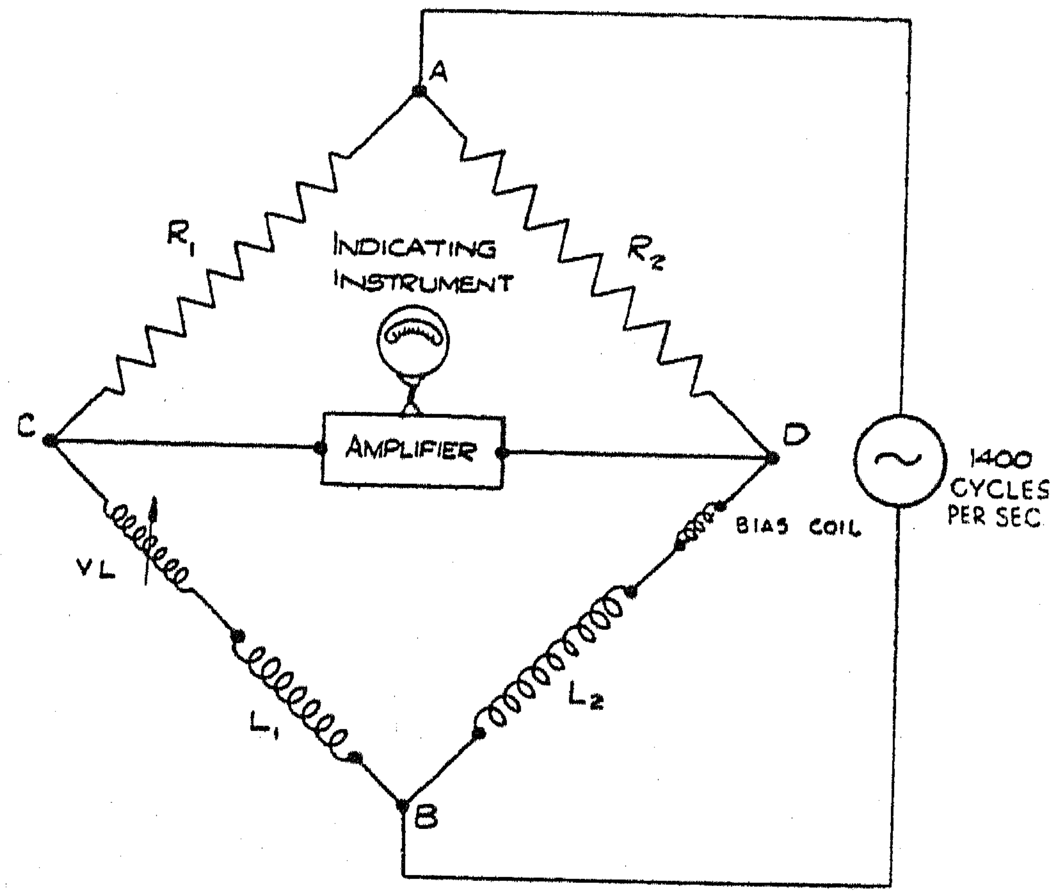

Fig. 4.—Simplified bridge arrangement finally adopted, using "differential" method.

FINAL DESIGN: CONSTRUCTIONAL DETAILS

The constructional details of the modified uniformity gauge are shown in Fig. 3. The saddle coils are replaced by two bobbin coils BB, each having 2 500 turns of No. 36 S.W.G. gauge enamelled wire mounted upon a stalloy silicon-steel laminated U-shaped core.

These features increased the inductance considerably, the value for the two coils in series being 0·5 henry. By means of trimmers the inductances of the coil units are made the same. The central screws CS can raise or lower the coils with respect to the frame F, thus increasing the range of sheath diameters for thickness measurements. Two roller bearings R are secured to either side of a light U-shaped aluminium frame A. Both roller bearings project 15 mils above the pole-faces P, to make an air-gap between the sheath S and the pole-tips. Small longitudinal surface irregularities are compensated for by the spring arrangement encased inside the knurled knob K, a latitude of $\frac{1}{4}$ in. being available. Four of these coil units are fitted at equidistant intervals on to a concentric aluminium frame. This frame is split into two halves, one split being hinged and the other having a quick-release catch so that when it is opened the gauge can be easily withdrawn from the sheath.

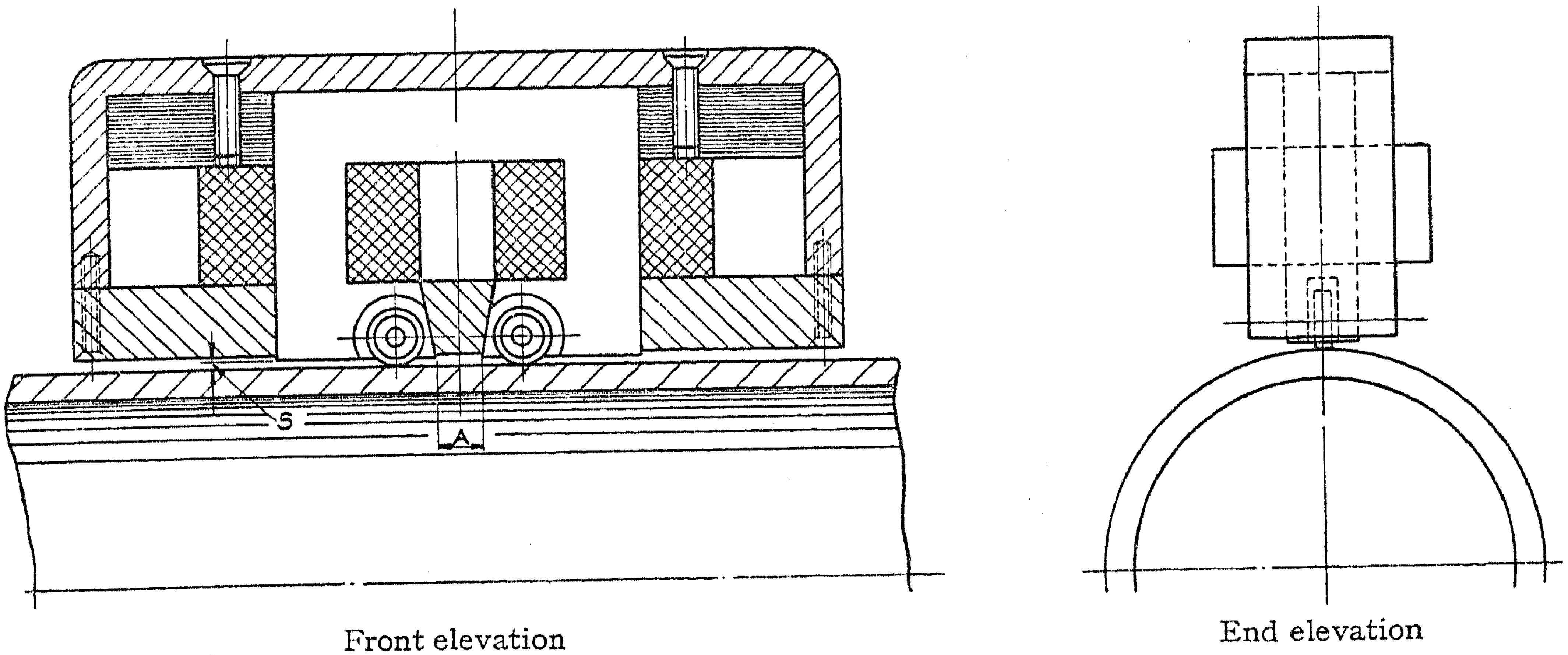

Fig. 5.—Proposed modification (not to scale).

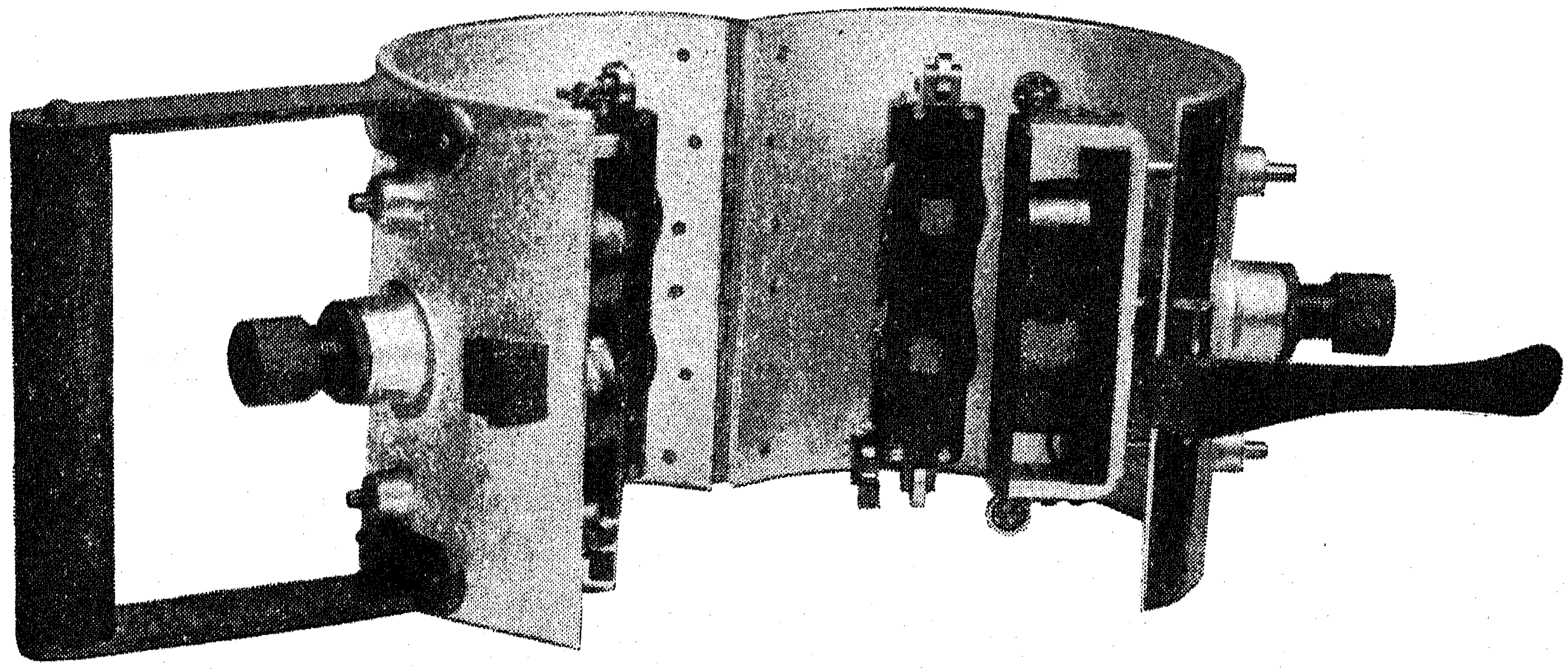

Fig. 6

CALIBRATION

No appreciable error was introduced when the apparatus was subjected to a heating test. The inductance-change per mil difference of thickness was approximately 160 times greater than in the previous model, and was sufficient to operate a moving-coil micrometer of the rectifier type, requiring a p.d. of 0·66 volt for a full-scale deflection of 750 microamperes.

THE BRIDGE

The indicating instrument is maintained at an artificial zero by unbalancing the bridge with the variable inductance VL (Fig. 4).

When unbalance occurs due to a change of inductance, the current in the instrument will change so that the pointer will go to the right or to the left of the arbitrary zero. Suppose, for example, the coil in the CB arm of the bridge decreases in inductance and DB remains constant, then the bridge will move towards balance, and the deflection will read to the left of the zero; and vice versa if DB decreases and CB remains constant. Temperature-changes affect both coils equally, and therefore do not alter the balance. It is seen that in this form the gauge measures only eccentricities, and not the actual thickness.

The non-inductive resistance arms R_1 and R_2 each have a value of 1 000 ohms. The inductances L_1 and L_2 are those of the two diametrically-opposite coil units, which are connected in series with their mid-point B connected to one side of the oscillator, whose other side goes to the point A. The variable inductance VL functions as in previous circuits. A 2-valve resistance-coupled amplifier incorporating transformer-coupled input and output (to facilitate matching) is used, and its input terminals are connected to the points C, D. Across its output terminals is the micrometer, which operates as described above. This instrument has an arbitrary uniform scale attached to it, with a centre zero. To set it to zero, the inductance VL is varied whilst the gauge is clamped to a sheath of kno uniform thickness. The gauge is then set up for te The sheath to be tested is passed through, and a mo ment of the pointer to one side of zero will mean t one side is thicker than the other.

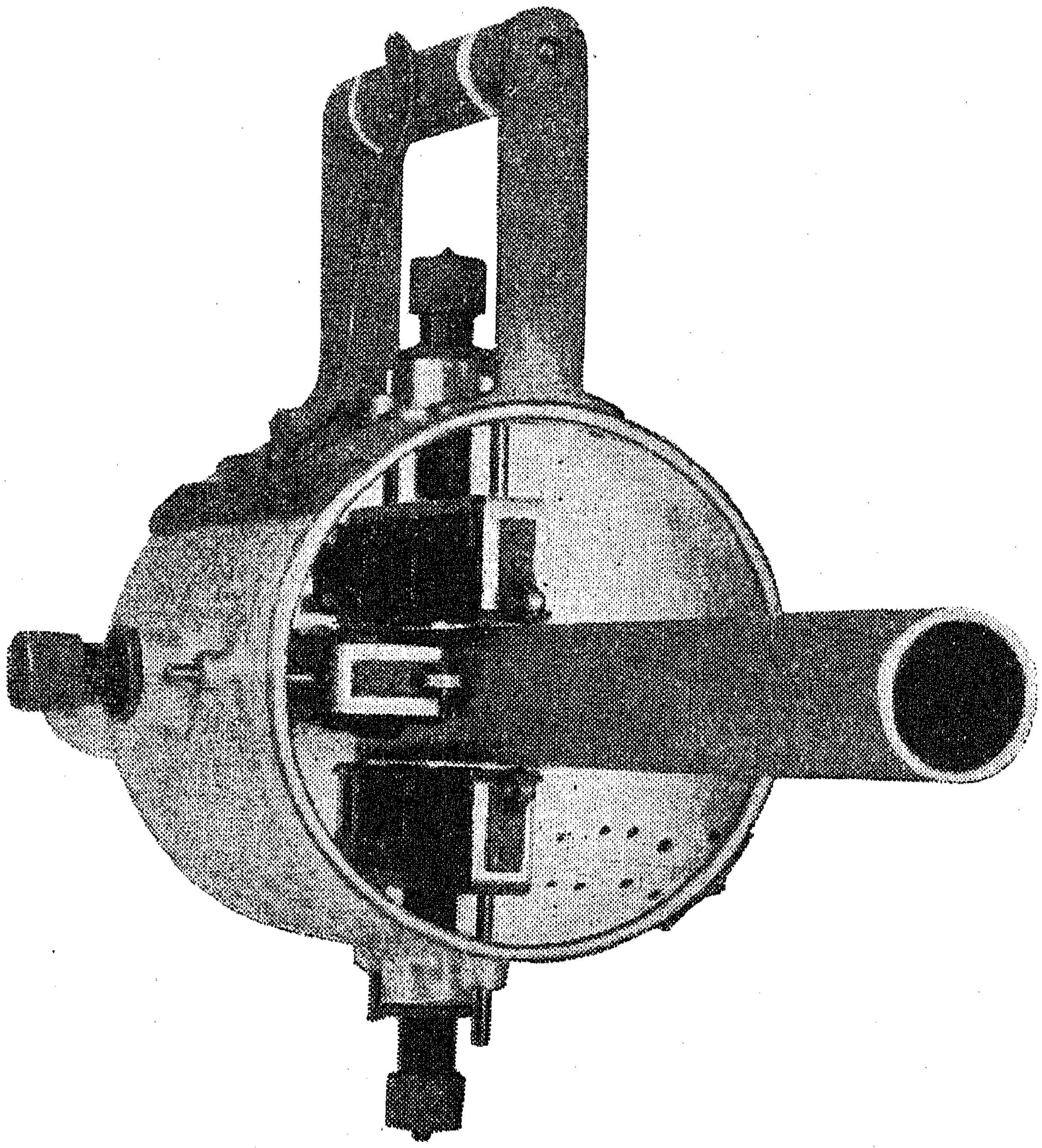

Fig. 7

PRACTICAL DIFFICULTIES

Although excellent performance was obtained straight sheaths, some difficulty was experienced wh the gauge had to be operated very near to the le press. Here the sheath formed an arc as the ra ascended during sheathing. This prevented the ope tion of the gauge within a few feet of the lead pre because the effect of the arc so formed was to cau the pole-tips to rub against the sheath. To overco this difficulty the apparatus was modified as shown Fig. 5, by reducing the roller-bearing-pitch and the pol pitch to a minimum.

The modified design combines the three essenti features of compactness, robustness, and simplicity operation. Two views of the gauge are shown in Figs. and 7 respectively.

AUTOMATIC CONTROL

By a slight modification of the indicating instrumen sheath irregularities can be automatically controlle during extrusion. Contacts fixed to the micromet dial can be made to operate relays, which in turn wi control the gas supplied to the die-heaters, and hen the product. Many other methods are possible.

CONCLUSION

With modern cables designed to stand ever-increasin voltages, sheath uniformity is becoming essentia Economy may be achieved by having a uniform sheat which reduces the necessary safety margin. These fact together with the sensitivity and practicability of th gauge described in this paper, lead the author to believ that an instrument of this nature will become an essentia part of lead-press equipment.

ACKNOWLEDGMENTS

The author wishes to express his thanks to Dr. D. M Robinson and Mr. G. King for their guidance and help

He is also indebted to Messrs. Callender's Cable an Construction Co., Ltd., in whose research laboratorie at Wood Lane, London, this work was carried out, fo their permission to publish the results.

THEORY AND PERFORMANCE OF THE ICONOSCOPE*

By V. K. ZWORYKIN, Ph.D., G. A. MORTON, Ph.D., and L. E. FLORY

(*Paper first received 20th May, and in revised form 18th September, 1937.*)

SUMMARY

Field tests have shown the present standard iconoscope to be a very satisfactory television pick-up device. However, from a theoretical point of view the efficiency of the iconoscope as a storage system is rather low. The principal factors responsible for the low efficiency are lack of collecting field for photo-electrons, and losses caused by the redistribution of secondary electrons produced by the beam.

Limits to the sensitivity of the standard iconoscope are set by the ratio of picture signal to amplifier and coupling-resistor "noise." Experimental and theoretical determinations indicate that an excellent picture can be transmitted with from 2½ to 6 millilumens per cm^2 on the mosaic.

Two methods are considered by which the sensitivity may be increased. The first is by the use of secondary-emission signal-multipliers and a low-capacitance mosaic, while the second makes use of secondary-emission image intensification. The sensitivity limits for the two cases are calculated.

INTRODUCTION

Experimental tests on the present standard iconoscope camera, illustrated in Fig. 1, have shown the iconoscope to be a very satisfactory television pick-up device. These tests include not only laboratory measurements but also extensive field tests by the National Broadcasting Co. at Rockefeller Centre, New York City. The conclusion arrived at from these tests is that the iconoscope is sufficiently sensitive to be used for outdoor pictures under a wide range of weather conditions, and in the studio without the need of unbearable illumination. However, it would be advantageous for both uses to have somewhat greater sensitivity. The following discussion, as well as dealing with the theory of operation of the standard iconoscope, describes two methods which have resulted in a marked increase in sensitivity. The tubes described are, however, still in the laboratory stage and not as yet ready for use in a commercial television system.

The principles and construction of the standard iconoscope, together with its associated equipment, have been described in detail elsewhere,† and a very brief description for the sake of continuity should suffice. The iconoscope consists of a photosensitive mosaic and an electron gun, assembled in a glass bulb which is highly evacuated. The electron gun is made up of an indirectly heated oxide-coated cathode, a control grid, a cylindrical first anode, and a second anode, also cylindrical but slightly larger in diameter. The gun assembly is shown diagrammatically in Fig. 2. This gun functions as an electron optical system for producing a narrow bundle of electrons which is made to scan the mosaic by means of magnetic deflecting coils.

The mosaic consists of a thin sheet of mica coated with a conducting metal film on one side, and covered on the other with a vast number of tiny, photosensitized silver globules. This mosaic is mounted in the blank in such a position that the electron beam strikes the photosensitized side at an angle of 30° from the normal, and the optical image to be transmitted is projected normal to the surface on the same side. The arrangement of these elements in the tube is shown in Fig. 3, while Fig. 4 shows an iconoscope with optically flat window.

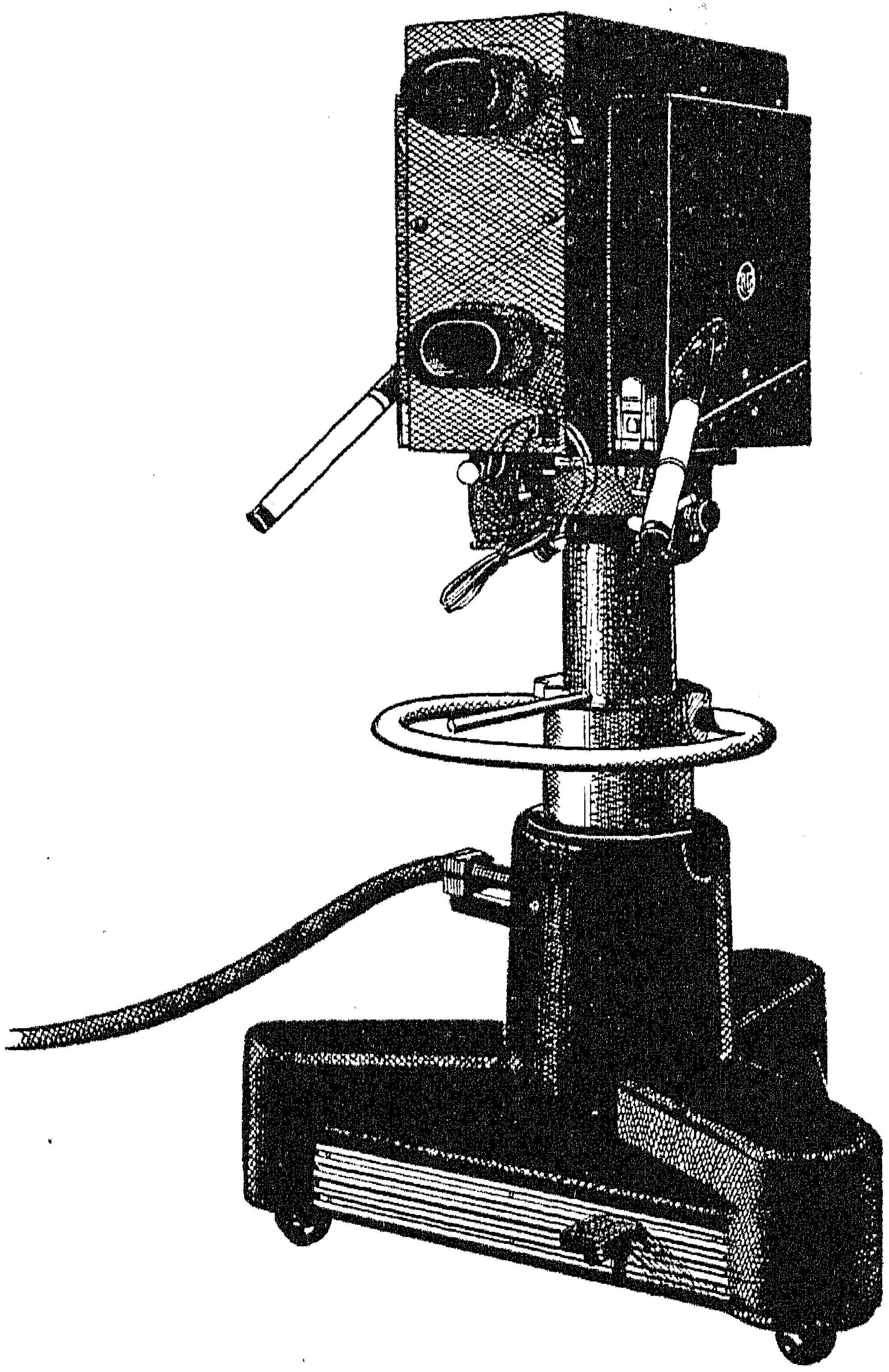

Fig. 1

Briefly, the iconoscope mosaic may be thought of as a 2-dimensional array of tiny photocells, each shunted by a condenser which couples them to a common signal lead. When the mosaic is illuminated these condensers are charged positively with respect to their equilibrium potential owing to the emission of photo-electrons from the photosensitive elements. For any particular element, this charging process continues for a time equal to the picture-repetition interval, i.e. until the beam in the process of scanning returns to the element. When the beam strikes it, it is driven to equilibrium, releasing its charge and inducing a current impulse in the signal lead. The train of impulses thus generated constitutes the picture-signal output of the iconoscope. This description serves to illustrate the general principles of the iconoscope, but is not sufficiently accurate to form the basis of an analysis of its operation.

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† See Reference (1).

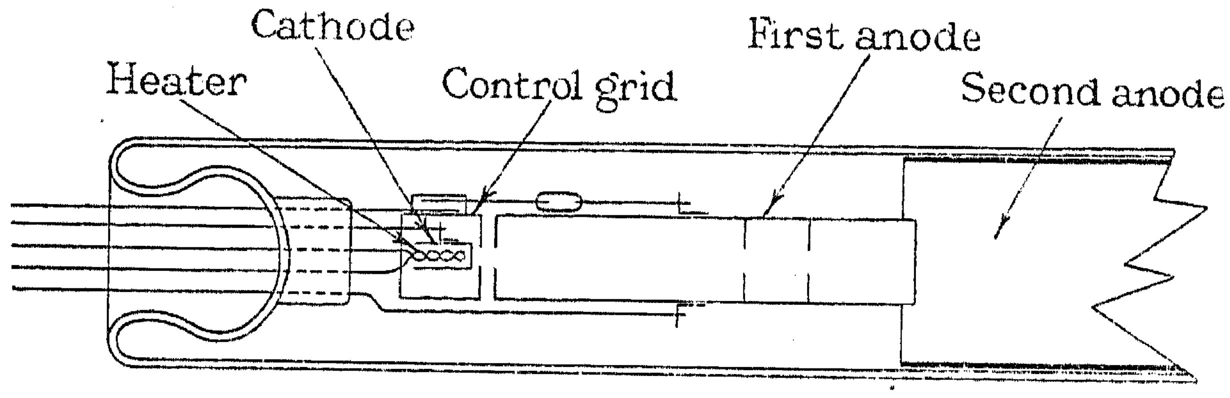

Fig. 2.—Electron gun.

MECHANISM OF OPERATION OF THE ICONOSCOPE

In considering the operation of the iconoscope, because of the fact that the silver globules are so small that a great number of them are under the beam at any instant the mosaic may be treated as a continuous surface which has infinite transverse resistance, and which has both a high secondary-emission ratio (in the neighbourhood of 5 to 7) and a good photosensitivity. This surface has a capacitance of about 100 $\mu\mu$F per cm^2 in the case of a standard tube. Considered in this way, it can be readily seen that the picture element is a purely fictitious concept when applied to the mosaic. Thus, instead of discussing the behaviour of discrete photo-electric elements, we shall deal with the mosaic as though it were a 2-dimensional continuum.

The average potential of the mosaic under bombardment, while no light is falling upon it, is between 0 and 1 volt negative with respect to the elements which collect the secondary emission from the mosaic, i.e. the second anode. However, the potential is not uniform over the entire surface. The area directly under the scanning beam will be at a potential of + 3 volts with respect to the second anode, this being the potential at which the secondary-emission ratio from caesiated silver becomes unity. Away from the point under immediate bombardment in the region which has just been traversed by the scanning beam the potential will be found to decrease, until at a distance equal to 25 %–30 % of the vertical scanning distance the potential reaches about $-1\frac{1}{2}$ volts with respect to the second anode. The rest of the mosaic is at this potential. This decrease in potential is caused by electrons which leave the point under bombardment and return to the mosaic as a more or less uniform rain of low-velocity electrons. Fig. 5 shows a map of the instantaneous potential distribution over the mosaic.

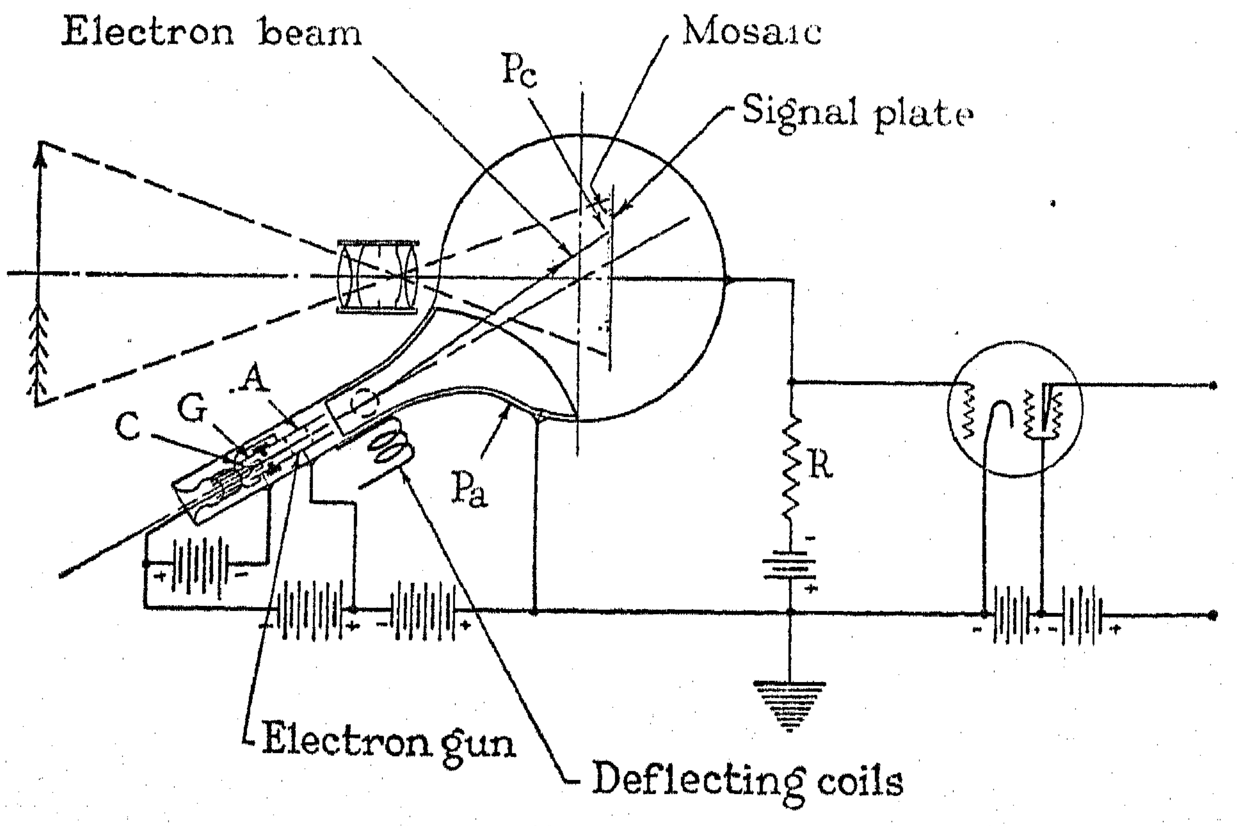

Fig. 3

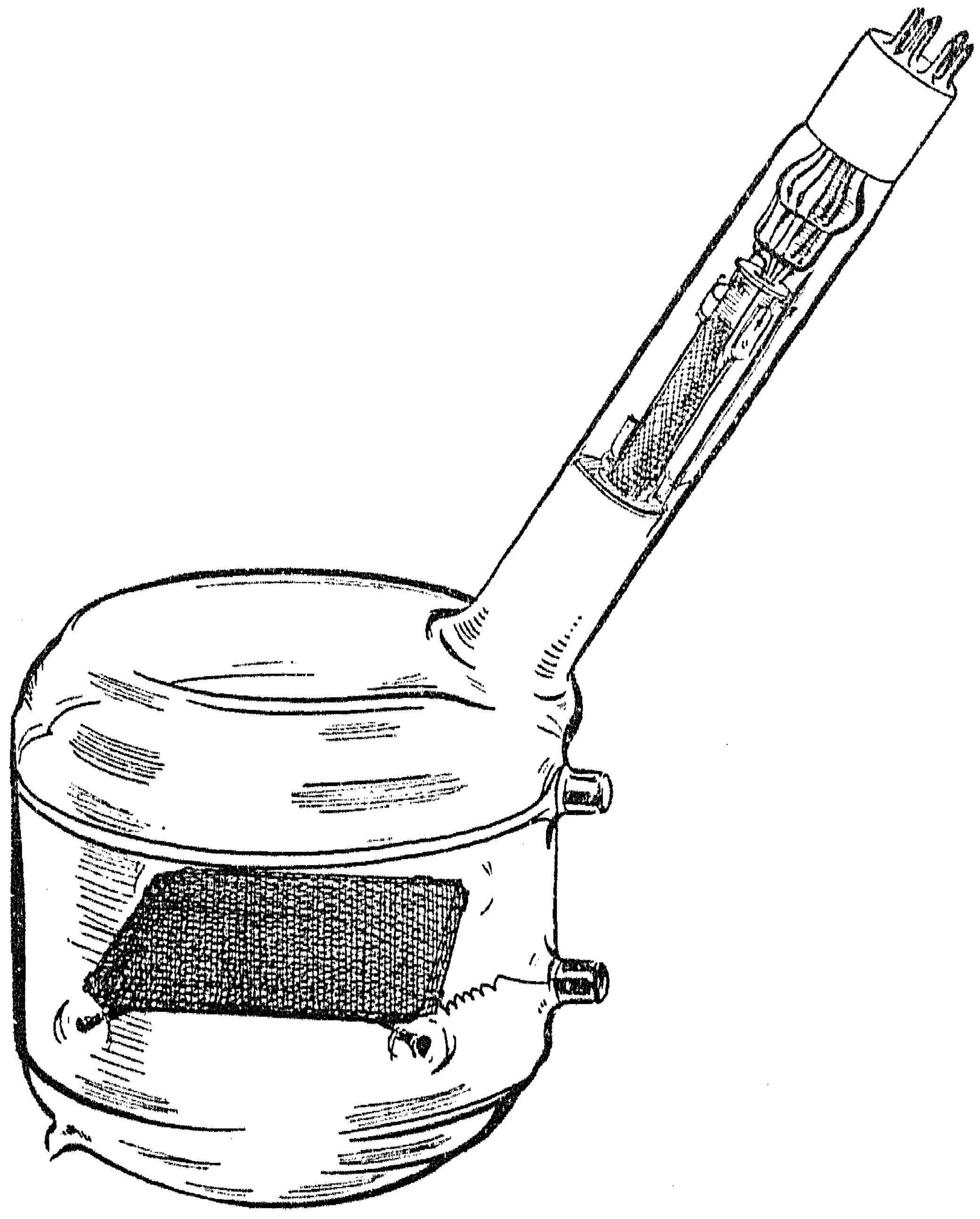

Fig. 4

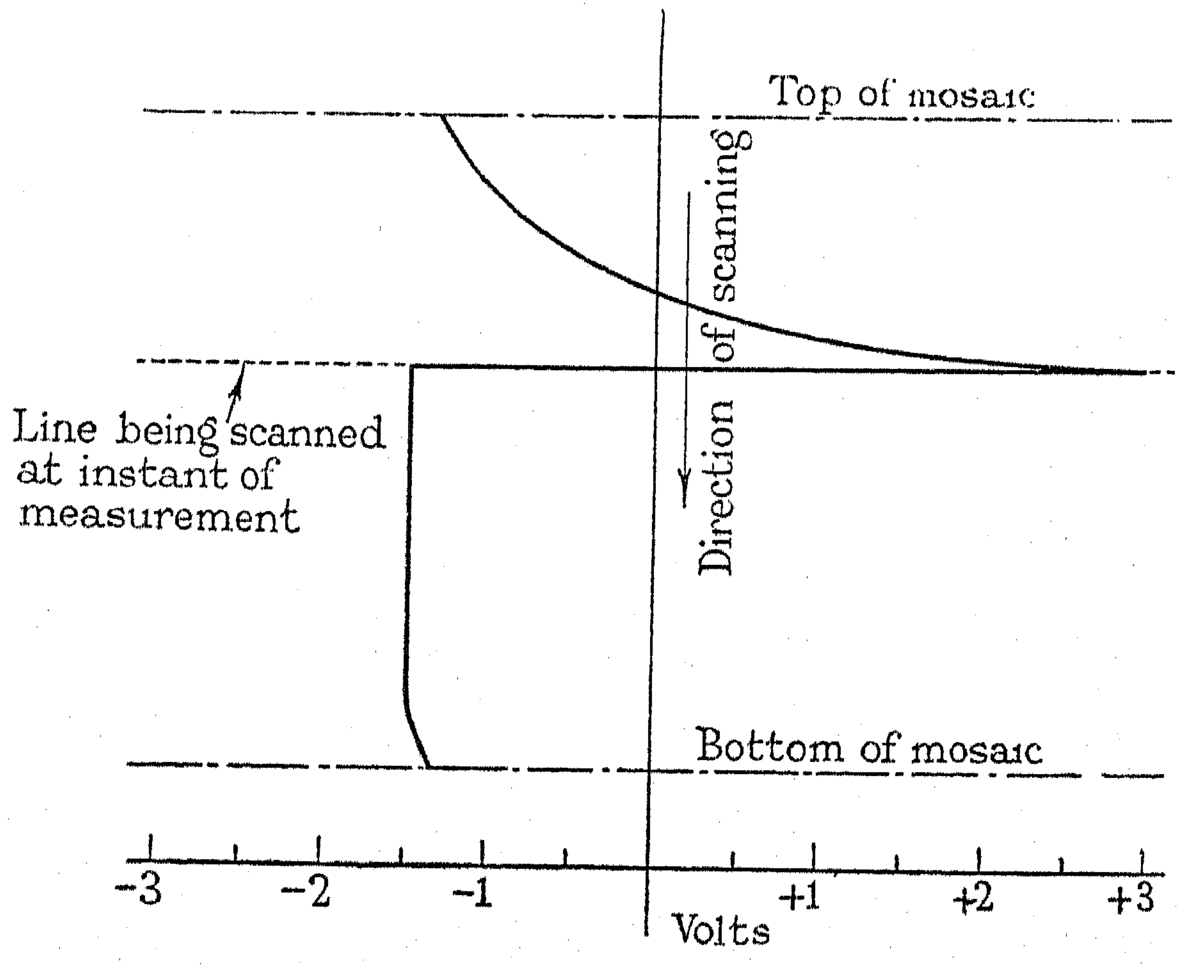

Fig. 5.—Instantaneous potential of the mosaic.

The scanning beam sweeping over the mosaic acts like a resistive commutator. The resistance in this case is determined by the current/voltage relation of the secondary electrons from the bombarded point. While this resistance is actually non-ohmic, we shall not introduce appreciable error if we assume it ohmic over the small voltage-range dealt with in the case of the iconoscope. Experimental measurements show this beam impedance, Z, to be given by the relation $Z = Z_0/i_b$, where i_b is the beam current and Z_0 is the coefficient of beam impedance. Z has a value between 1 and 2 ohm/ampere.

For purposes of computation, the beam current will be taken as $0 \cdot 5$ microampere, the spot as a square of $0 \cdot 025$ cm. side, and the linear spot velocity as $1 \cdot 6 \times 10^5$ cm. per sec.

Any small element of area, ds, of the mosaic when it is swept over by the scanning beam must change its potential from $-1\frac{1}{2}$ volts to its equilibrium value of approximately $+3$ volts. The capacitance of this area will be $C = C_0 ds$, where C_0 is the capacitance per unit area. The impedance through which this capacitance is discharged will be $Z = Z_0/(\rho ds)$, ρ being the current density of the beam. The equation of the discharge will therefore be

$$V = \left[V_2(xy) - V_1(xy)\right]\left[1 - e^{-t\rho/(C_0 Z_0)}\right] \quad . \quad (1)$$

In this equation, V = change in potential of ds, $V_2(xy)$ = equilibrium potential at point xy under beam, $V_1(xy)$ = potential before bombardment, and t = time.

In order that the elements may reach equilibrium, the condition

$$V \simeq V_2 - V_1$$

must be fulfilled. For this to be true, the relation

$$\frac{Z_0 C_0}{\rho} < T \quad .$$

(where T = length of time for which the beam is on the element ds, or
$T = h/V$, where h is the spot diameter and V is the beam velocity)

must be satisfied. From the operating conditions, we find that $T = h/V = 1 \cdot 5 \times 10^{-7}$ sec. and $Z_0 C_0/\rho = 1 \cdot 2 \times 10^{-7}$ sec. Thus the requirements for establishing equilibrium are fulfilled.

In the above expression both V_1 and V_2 are given as functions of the co-ordinates of the mosaic, x and y. This is because both the equilibrium under the beam and the equilibrium away from the beam are not constant over the surface.

The net current leaving the elemental area under these conditions will be

$$di_e = -\left(C_0 \frac{dV}{dt}\right) ds \quad . \quad . \quad . \quad . \quad (2)$$

Since the beam current reaching the element is $-\rho ds$, the total current from the element is

$$di_t = -\left(\rho + C_0 \frac{dV}{dt}\right) ds$$

This entire current will not reach the second anode because, on the average, as much current must reach the mosaic as leaves it. Let $\chi(xyV)$ be the fraction of this current which reaches the second anode; then the current to the second anode can be written as

$$di_s = \chi(xyV)\left(\rho + C_0 \frac{dV}{dt}\right) ds \quad . \quad . \quad . \quad (3)$$

The instantaneous current, i_s, reaching the second anode, is given by the integral of the above expression over the area of the scanning beam. Since the current i_s carries the picture signal, the solution of equation (3) would be very desirable. This integration, however, cannot be performed since the function $\chi(xyV)$ is not known.

It is possible to make certain approximations which will enable the calculation to be made of an average value for the redistribution function. Since the mosaic is an insulator, the average value of its function must be given by

$$\bar{\chi} = \frac{i_b}{i_T} = \frac{i_b}{i_b + i_e} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

In this equation, i_b is known and i_e can be found as follows:—

$$i_e = \int C_0 \frac{dV}{dt} ds$$

But we have

$$V = [V_2 - V_1]\left[1 - e^{-t\rho/(C_0 Z_0)}\right]$$

and

$$\frac{dV}{dt} = (V_2 - V_1)\left(\frac{\rho}{C_0 Z_0}\right) e^{-t\rho/(C_0 Z_0)}$$

$$ds = hVdt$$

Therefore we can write

$$i_e = \frac{hV\rho}{Z_0}(V_2 - V_1)\int_0^T e^{-t\rho/(C_0 Z_0)} dt$$

$$\simeq hVC_0(V_2 - V_1)$$

and

$$\bar{\chi} = \cfrac{1}{\cfrac{1 + hVC_0(V_2 - V_1)}{i_b}} \quad . \quad . \quad . \quad (5)$$

Evaluating this function, using the constants of the iconoscope, we find that $\bar{\chi} \simeq 0 \cdot 25$. This means that, out of the total charge released by an element when struck by the beam, only about 25 % will reach the second anode, the remainder being returned to the mosaic. In other words, only about 25 % of the stored charge is available for producing the picture signal.

As was mentioned above, $V_1(xy)$, $V_2(xy)$, and $\chi(xyV)$ are not constant over the mosaic, even when it is in darkness. As a consequence, there is a variation in the current reaching the second anode as the mosaic is scanned. This gives rise to a spurious signal which, if not compensated, produces irregular shading over the picture. The importance of this spurious signal is sufficient to warrant further discussion. It is evident from the nature of the factors upon which it depends that it may be regarded as divided into two parts. The first is the stored signal, which depends upon $V_1(xy)$, while the second is an instantaneous effect, depending upon the variation of $V_2(xy)$ and $\chi(xyV)$ over the mosaic.

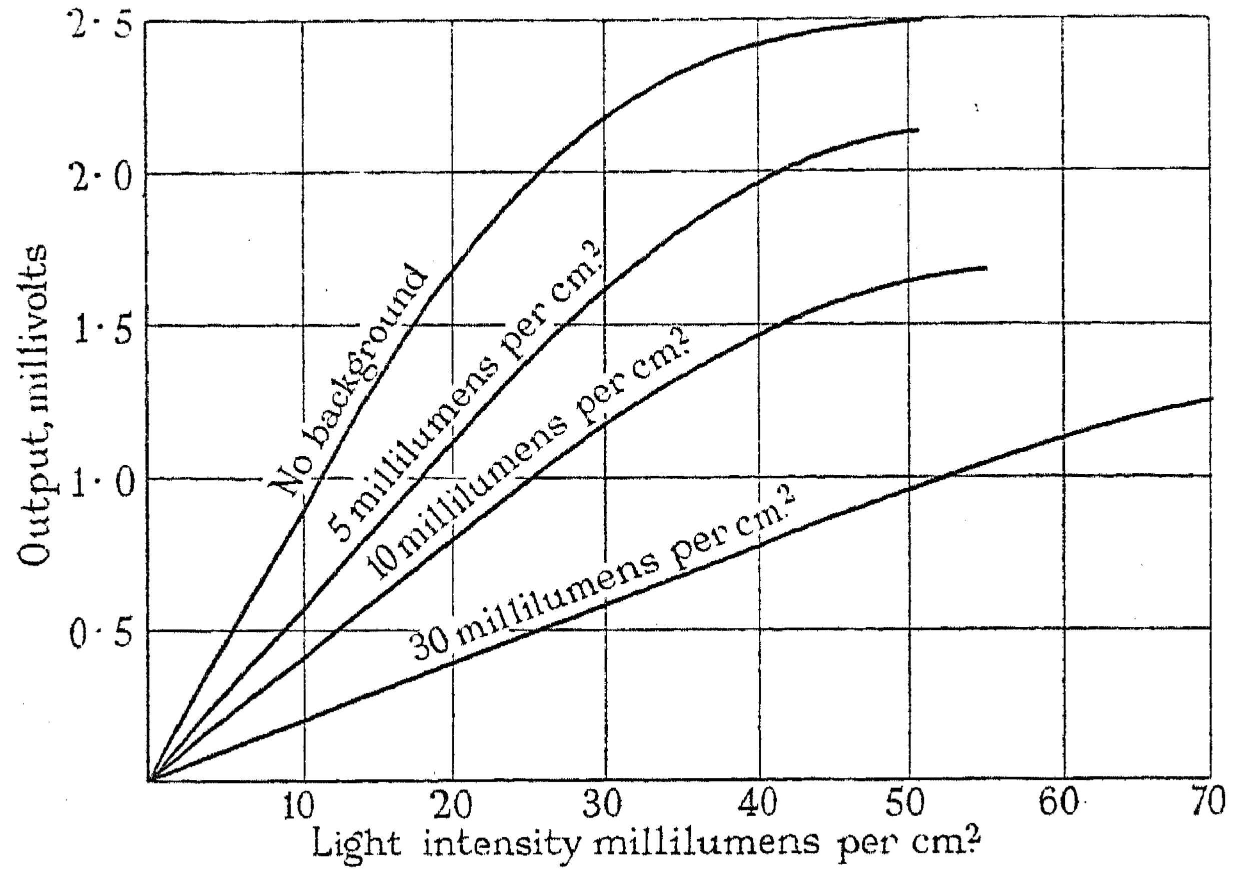

Fig. 6.—Variation of output with light intensity, for different values of background illumination.

The instantaneous component can be demonstrated very strikingly if a metal plate is substituted for the mosaic in an iconoscope. When this plate is scanned in the ordinary way, it being maintained at a potential close to that of the second anode, a spurious signal is produced very similar to that from the mosaic. While the mechanism of generation of this signal is not exactly the same as that in the case of the mosaic, it is quite similar. If the potential of the plate is made negative or positive with respect to the second anode, the secondary emission will be suppressed, or saturated, and the signal will disappear. In practice, the spurious signal from the iconoscope is compensated for by means of an electrical correcting network. Considerable work has been done, and further work is in progress, on methods of overcoming the effect of the spurious signal or entirely eliminating it.

When an optical image is projected on to the mosaic, the illuminated area emits photo-electrons in proportion to the light falling on it. As a consequence, this area reaches a less negative final potential than an unilluminated area. In this connection it should be pointed out that, although the mosaic receives a continuous redistribution current, this current is very little altered by small changes in potential over small areas. In other words, the impedance shunting any element is very high. As a result of the difference in $V_1(xy)$ for an illuminated and an unilluminated region, there is a change in i_s. This fluctuation constitutes the picture signal.

Besides the inefficiency consequent on the redistribution losses, the photo-emission is also inefficient owing to the small fields drawing the photo-electrons away from the mosaic. The effective photo-emission of the mosaic in the standard iconoscope is only about 20 % to 30 % of its saturated value. This means that the overall efficiency of the iconoscope is only 5 % to 10 %. In spite of this inefficiency, the great advantage resulting from the use of the storage principle makes the iconoscope a very effective pick-up device.

Before we leave the discussion of the mechanism of operation of the iconoscope, mention should be made of the phenomenon of line sensitivity which results from the variation in potential over the surface of the mosaic. Referring to Fig. 5, it will be seen that the line on the mosaic just ahead of the scanning beam is subject to a strong positive field, and consequently has high photo-electric efficiency. The line is, in consequence, extremely sensitive. This can be demonstrated very strikingly in the following way. The image from a continuously-run motion-picture film (e.g. a picture projected by a moving-picture machine from which the intermittent shutter has been removed) is projected on to the mosaic of the iconoscope. The film is run at such a rate that the frame speed is equal to the picture frequency, and in

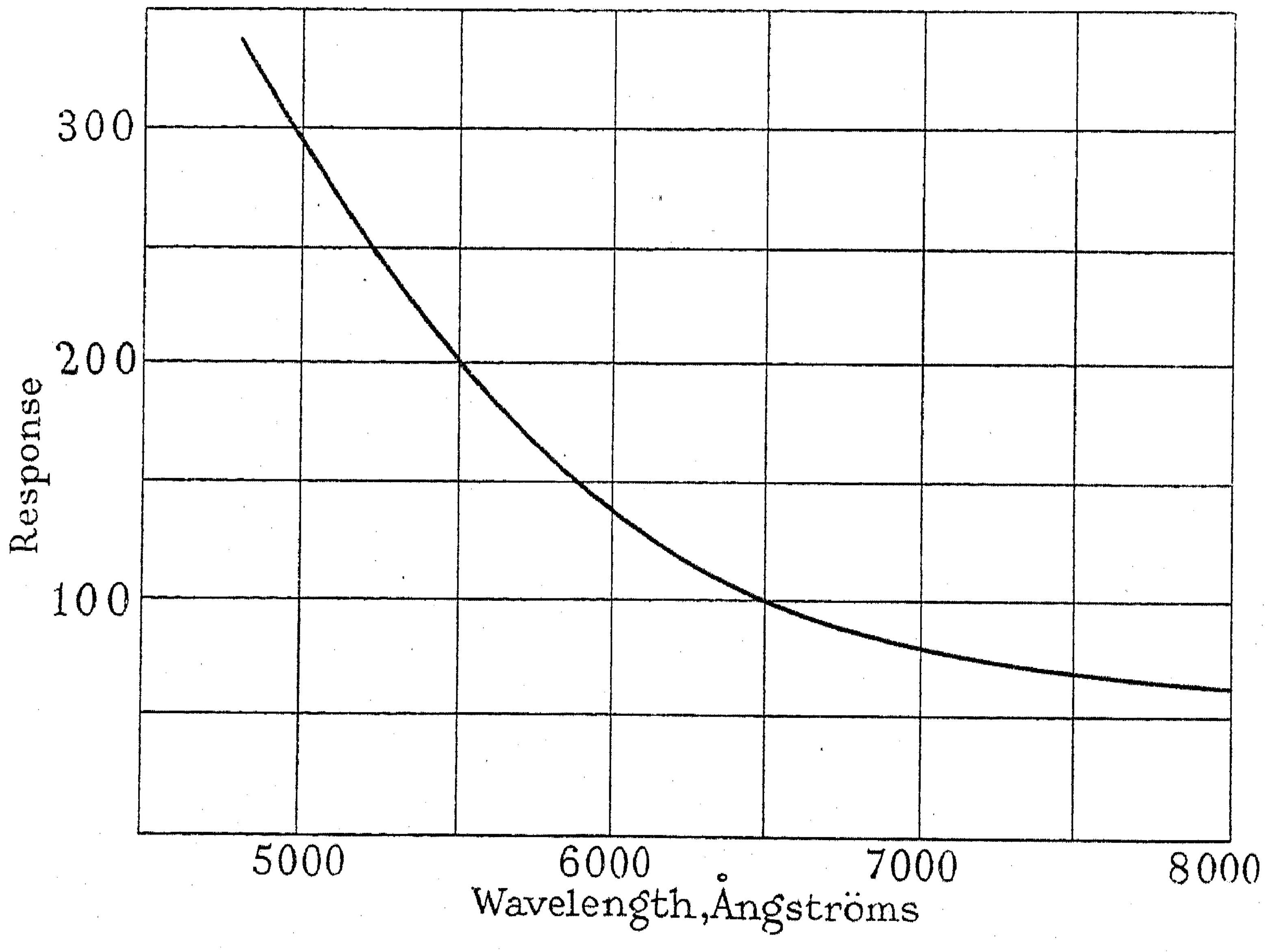

Fig. 7.—Colour response of standard iconoscope.

such a direction that the picture moves in the opposite direction to that of scanning. Under these conditions the iconoscope is found to transmit a clear image of two frames of the moving-picture film, although to the eye there appears to be only a blur of light on the mosaic.

From the above description of the mechanism of operation of the iconoscope it is apparent that the efficiency decreases as the light intensity increases. Fig. 6 shows a family of measured curves illustrating this effect. The output is measured in millivolts across a 10 000-ohm coupling resistance, and the light input in lumens per cm^2 on the mosaic. The curve showing the greatest response represents the signal output from a small illuminated area when the remainder of the mosaic remains unilluminated. The effect of a background illumination over the entire mosaic is shown by the remaining curves of the family.

The colour response of an iconoscope depends upon the activation schedule and the operating conditions involved. Fig. 7 shows the colour response measured on the present type of standard iconoscope.

CALCULATION OF THE SENSITIVITY OF THE ICONOSCOPE

So far, we have considered only the magnitude of the signal output. If it were possible to amplify the signal output indefinitely without introducing spurious effects, the problem of attaining high sensitivity would merely be one of increasing the amplifier gain. However, the picture amplifier amplifies not only the signal output from the iconoscope but also the voltage generated by the thermal agitation in the coupling resistor (or other coupling device). If the voltage generated by the picture signal becomes of the same order as these fluctuations, the picture becomes lost in " noise." This sets a definite limit to the sensitivity that can be obtained.

In making any calculations concerning the sensitivity of the iconoscope we are faced with the problem of assigning quantitative values to the psychological effect of picture/noise ratio. Tests have been made to determine the effect on the observer of various ratios of peak picture-signal in an average picture, to root-mean-square noise. It has been found that if the r.m.s. noise is equal to 30 % of the picture signal, the picture is still recognizable, but the resolution is decreased and the picture is tiring to watch. In addition, if the ratio remains constant but the picture amplitude is decreased, the noise becomes less objectionable; however, there is no increase in the effective resolution. If the picture/noise ratio is 10 : 1, a very good picture can be obtained but the noise is still very noticeable. Such a picture is completely usable and has fair entertainment value. When the noise is reduced to 3 % of the picture, it becomes practically unnoticeable and the picture may be regarded as excellent.

Let us base our calculation of sensitivity on an allowable noise/picture ratio of 10 %. While under these conditions the amount of noise would be greater than would be tolerated if conditions made it possible to avoid such a high noise/picture ratio, nevertheless such a picture would have reasonably good entertainment value and could be broadcast, particularly where programme continuity made transmission necessary. To make the calculation the following data are necessary: Area of mosaic (A), 128 cm^2; photosensitivity (p), 7 μA per lumen; overall efficiency (k), 0·05; coefficient of thermal e.m.f. (K_1), $1 \cdot 6 \times 10^{-20}$; coupling resistance ($R$), 10 000 ohms; frequency band (f), 2×10^6 cycles per sec.

If the region of maximum illumination receives a light flux F lumens per cm^2, the signal from the iconoscope from this point will be

$$I = Fpk\frac{A}{n}\frac{T_0}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$= FpkA$$

where n = number of elements, T_0 = picture (frame) time, and T = time for which the beam is on one picture element. But, since $T_n = T_0$, and substituting the values given above, the instantaneous current pulse is

$$i_s = 4 \cdot 5 \times 10^{-5} F \text{ amp.}$$

Since this is fed through a 10 000-ohm resistor, the picture voltage is

$$V_s = 0 \cdot 45\, F \text{ volts}$$

The coupling resistor alone does not generate the entire noise found in the picture amplifier. Noise voltages generated in the first amplifying valve and first plate resistor are each present in appreciable amount, particularly in an amplifier covering as broad a frequency band as is required. In order to take into account these factors, it will be assumed that the noise in the amplifier is equivalent to a resistance of 30 000 ohms across the input. The noise voltage will therefore be:—

$$V_N^2 = K_2 fR, \text{ where } K_2 \text{ is the shot coefficient}$$
$$= 9 \cdot 6 \times 10^{-10}$$

or an r.m.s. noise voltage of

$$\overline{V}_N = 3 \cdot 1 \times 10^{-5}$$

The picture/noise ratio under these conditions is therefore

$$N = 1 \cdot 45 \times 10^4 F$$

Further, if the minimum usable ratio is assumed to be 10, the smallest amount of light falling on the mosaic sufficient to give an adequate picture will be 7×10^{-4} lumen per cm^2. This corresponds to illumination on the high lights, and is of course somewhat higher than the average illumination of the picture. On the same basis, the illumination required to produce an excellent picture, i.e. where the noise is only 3 % of the picture signal, would be as follows: $N = 1 \cdot 45 \times 10^4 F = 33$; $F = 2 \cdot 3 \times 10^{-3}$ lumen per cm^2. Actual measurements on an average iconoscope show that an excellent picture can be transmitted from an object having a surface brightness of 20 to 50 candles per sq. ft., using an $f/2 \cdot 7$ lens. The illumination on the mosaic under these conditions will be:—

$$F = \frac{\pi B}{4(\text{Focal length of lens})^2} = 2\tfrac{1}{2} \text{ to 6 millilumens per cm}^2$$

When allowance is made for reflection losses in the optical system and for the psychological element, the agreement will be seen to be fairly good.

METHODS OF INCREASING THE SENSITIVITY OF THE ICONOSCOPE

The problem of increasing the sensitivity of the iconoscope may be approached in three different ways: First, by keeping the signal sensitivity the same and reducing the noise generated; second, by increasing the quantity of charge per unit light flux acquired by the mosaic; third, by increasing the overall efficiency of the iconoscope. The third method has been studied extensively, and laboratory iconoscopes have been made with efficiencies as high as 50 %. This work is still in the early experimental stage, however, and will not be discussed here.

Let us consider the first method of increasing the sensitivity. Noise reduction is possible because of the fact that the effective circuit carrying the signal from the iconoscope is completed through the secondary emission from the mosaic. In other words, when the coupling resistor and amplifier are connected to an electrode which collects the secondary emission, a signal can be obtained which is equal to that from the signal plate. If these secondary electrons are led into a secondary-emission multiplier instead of being collected, it is possible to obtain the signal from the multiplier and thus completely eliminate the noise that would be introduced by the conventional coupling-resistor and amplifier.

Before taking up the question of the type of multiplier suitable for this purpose, or the methods used to get the electrons from the mosaic into the multiplier, let us consider the sensitivity and noise relations resulting from this scheme. The picture output will be equal to the signal at the mosaic times the gain of the multiplier; the latter will be written as B^n, B being the gain per stage and n the number of stages. Hence

$$I_s = FpkAB^n$$

On the other hand, the noise will be essentially the shot noise in the secondary emission from the mosaic. More exactly, the noise* is

$$I_N^2 = \frac{B^{2n+1}}{B-1} K_2 f \,.\, 2i_b$$

Therefore, the picture/noise ratio will be

$$N = \frac{I_s}{I_n} = \frac{kA}{\sqrt{(K_2 f)}} \sqrt{\left(\frac{B-1}{2B}\right)} \frac{F}{\sqrt{i_b}} \quad . \quad . \quad (7)$$

Evaluating this, we find

$$N \simeq 40 \frac{F}{\sqrt{i_b}}$$

In actual practice the beam current in a standard iconoscope is about 0·5 microampere. If N is assumed to be 10, the illumination required will be

$$F \simeq 2 \times 10^{-4} \text{ lumen per cm}^2$$

This is to be compared with the result where a normal amplifier was used, and where the illumination was 7×10^{-4} lumen per cm^2; that is, this represents an increase in sensitivity of about 3 times.

The interesting point about this multiplier iconoscope is, however, that its sensitivity depends upon the beam current; therefore, if we can reduce the beam current without decreasing the efficiency, the iconoscope becomes more effective. It is not possible, in a multiplier iconoscope using a standard mosaic, to reduce the beam current without loss in efficiency owing to the increase of discharge time of the elements. When this condition occurs, the efficiency falls off and, furthermore, moving objects blur. In order to decrease the time-constant so that the beam current can be decreased, it is necessary to reduce the element capacitance. The simplest method of accomplishing this is by using a thicker insulating layer for the mosaic. Assuming that the time-constant is fixed, the beam current should be inversely proportional to the capacitance; in other words, approximately proportional to the mosaic thickness. It is interesting to carry the calculation down to the limiting case and to see what is the maximum sensitivity obtainable by this method. Obviously, the beam current cannot be reduced beyond the point where it becomes equal to the photocurrent. Under these conditions, we can calculate the sensitivity as follows:—

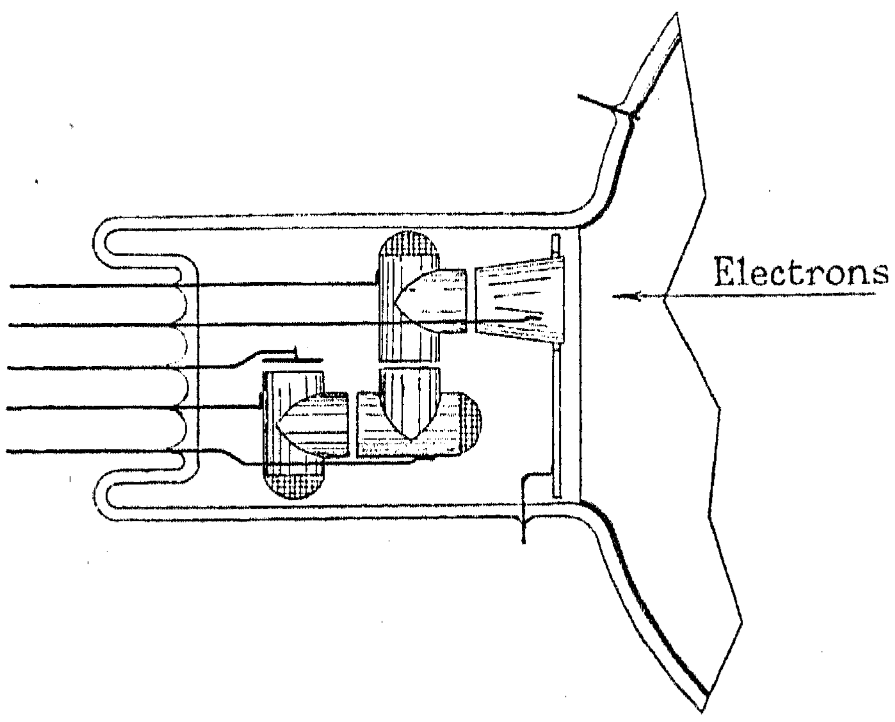

Fig. 8.—" T " type multiplier.

$$i_{phot.} = k'Fpah$$

where a and h are the length and height of the region considered, and k' is the fraction of photocurrent leaving the mosaic. The instantaneous beam equivalent must therefore be

$$i_0 = k'Fpah\frac{T_0}{Ta} = FpAk'$$

$$I_s = FpkA$$

Hence the picture/noise ratio will be

$$N = \frac{I_s}{I_n} = \frac{pkA}{\sqrt{(k_2 f)}} \sqrt{\left(\frac{B-1}{B}\right)} \frac{F}{\sqrt{2FpAk'}} \quad . \quad (8)$$

$$= \sqrt{\left[\frac{pk^2A(B-1)}{2k'K_2 fB}\right]} \sqrt{F}$$

Assuming, as before, that N must be at least 10, the minimum light that can be used will be $F = 5 \times 10^{-6}$

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* See Reference (2).

lumen per cm². This would be the smallest amount of light that would suffice to transmit a satisfactory picture when noise suppression of this type was used. The value for the sensitivity just given must be regarded purely as a theoretical estimate. In practice, no tube has yet been made based on this principle with a sensitivity greater than 10 to 20 times that of the standard iconoscope.

Having arrived at certain theoretical conclusions as to the ultimate sensitivity that can be attained, let us now consider the practical details of construction. The multiplier suitable for this purpose is preferably one which does not involve the use of a magnetic field: it must be capable of multiplying a comparatively broad beam of electrons rather than a sharply defined spot, and must have a high gain per stage. It has been found that the " T " type* multiplier, whose construction is shown in Fig. 8, serves very adequately. There are, however, a number of possible types of multipliers that might be used.

In order to get the electrons away from the mosaic, a disc—run at from 25 to 100 volts positive with respect to the second anode—is placed at the entrance of the protuberance containing the multiplier. This disc is perforated with an aperture behind which is mounted a small truncated cone at a high positive potential, carrying the electrons through the aperture and into the multiplier. The disc, because of its area, determines to a great extent the field close to the mosaic, while the cone governs the field distribution close to the disc.

Several tubes were made to determine the most suitable location for the multipliers, with the results shown in the Table in col. 2 on this page.

Because of optical reasons, it is a difficult problem to locate the multiplier directly in front of the mosaic. It was found, however, that two multipliers located at 30° on either side of the normal to the mosaic, collected all of the electrons leaving the mosaic. This type of iconoscope is shown in Fig. 9. While work is still being done on this development, very satisfactory pictures under conditions of low illumination have been obtained from this type of tube. The principal problems yet to be dealt with are those of activating the multipliers and the mosaic simultaneously, and of obtaining a uniform distribution of the picture.

The second method of increasing the sensitivity of the iconoscope is by the use of secondary-emission image intensification. This can be accomplished by allowing the electron image produced in some form of image tube to fall on a mosaic constructed in such a way that the elements extend through the mosaic. The elements on the side of the mosaic on which the electron image is projected are made secondary-emissive, so that for every electron striking the mosaic 6–8 electrons are emitted. Thus, the stored signal will be several times that which would be due to the original photo-electric current. The scanning beam sweeps across the back of the mosaic, removing the stored picture in the same way that the picture is removed from the ordinary one-sided mosaic. The gain in sensitivity will be proportional to the intensification at the mosaic. Furthermore, it is possible to produce semi-transparent photocathodes of the type used in the image tube with more than twice the photo-sensitivity of the ordinary mosaic. Considering both

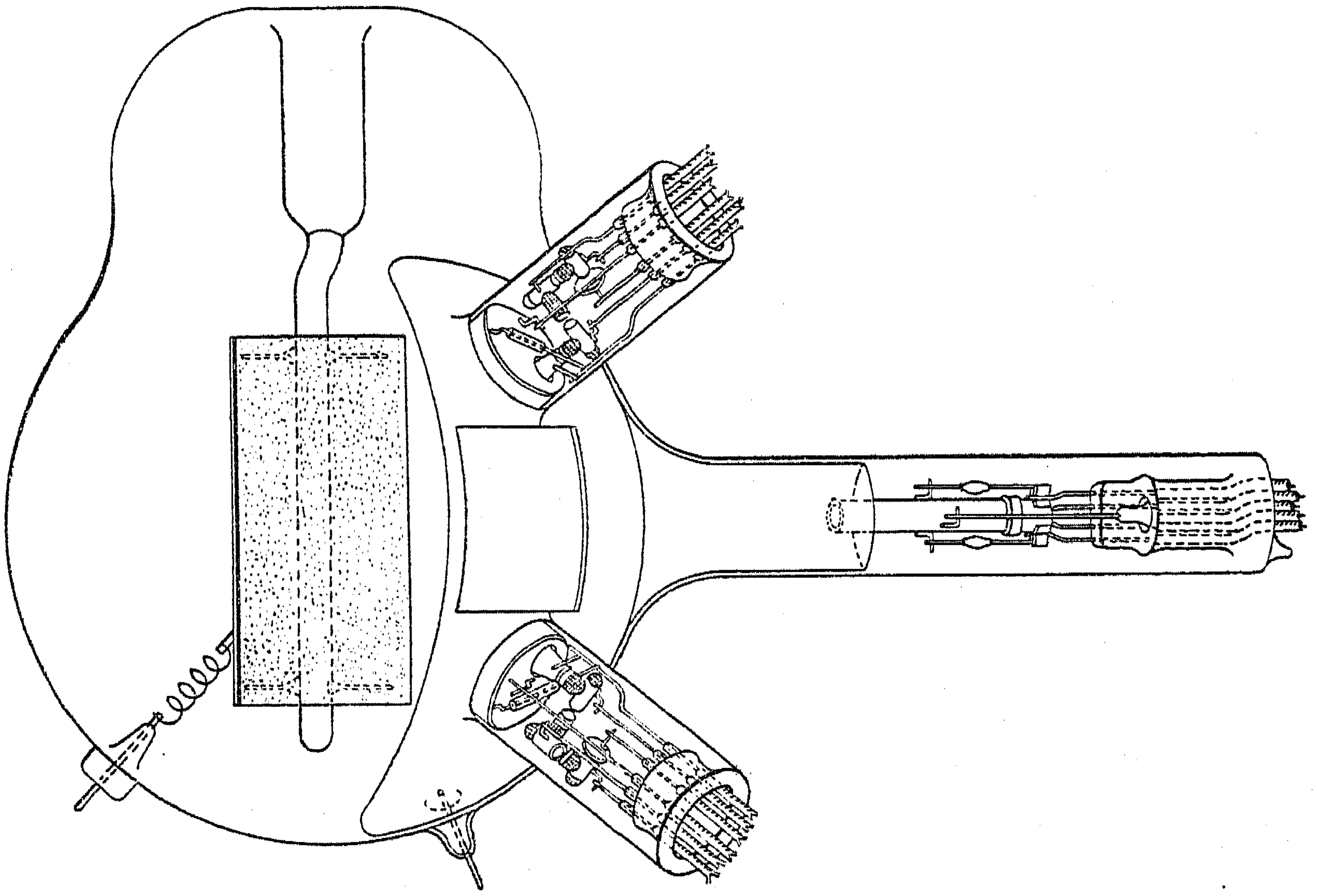

Fig. 9.—Signal-multiplier iconoscope.

Position	Percentage of electrons collected
Behind mosaic	10
Side of mosaic	50
At angle of 30° to normal	80
Front	100

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* See Reference (2).

these factors, it is possible to increase the sensitivity by from 10 to 15 times.

Before examining the details of this type of tube, let us consider the limiting sensitivity that can be attained in this way. First, the gain obtainable is not of course limited to that which can be obtained from one stage of secondary-emission multiplication. It is perfectly possible, and has been accomplished in experimental tubes, to allow the electron image from an image tube to fall upon a secondary-emitting surface, and with a second electron optical system to refocus this enhanced image. Let us assume that this process can be repeated as many times as is desired, and the multiplied image be projected on a two-sided mosaic. In this way, the charge image stored on the mosaic may be made as large as is desired. However, as was the case with the low-capacitance tube, there are definite limits to the sensitivity that can be attained. The limit in this case is due to the statistical fluctuation in the photocurrent emitted from the photosensitive cathode upon which the image is initially projected.

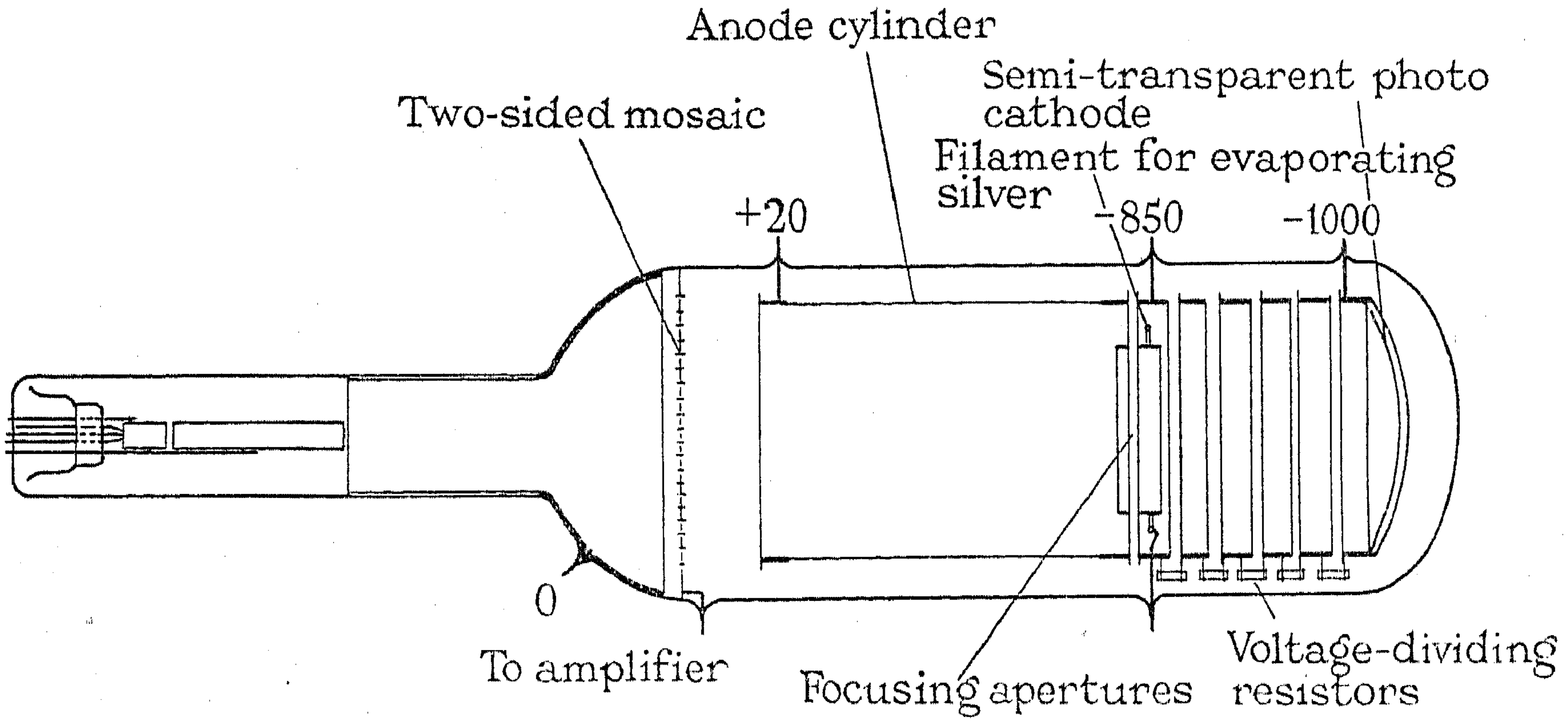
Anode cylinder
Two-sided mosaic
Semi-transparent photo cathode
Filament for evaporating silver
+20
-850
-1000
0
To amplifier
Focusing apertures
Voltage-dividing resistors

Fig. 10.—Image-multiplier iconoscope.

In order to estimate the ultimate sensitivity, let us assume that the gain of each stage of the secondary-emission multiplier is sufficiently great for the picture/noise ratio at the cathode to be not appreciably greater than it is at the mosaic. This is equivalent to assuming that the fraction $(B - 1)/B$, used above in multiplier calculations, is equal to unity, which is amply justified when gains of 7 or 8 per stage can be obtained. It can be shown that, if q is the photo-electric charge emitted by one picture element during one frame time, the mean-square fluctuation will be

$$\overline{q_N^2} = eq$$

If, as before, we assume that the root-mean-square fluctuation should be 10 % of the total charge, we have

$$N = \frac{q}{q_N} = \frac{q}{\sqrt{(eq)}} = \frac{i_pT_0}{\sqrt{(ei_pT_0)}}$$

But

$$i_p = Fap = \frac{FAp}{n}$$

where i_p is the photo-emission from one element, and a the area of an element. Thus, we have

$$N = \sqrt{\left(\frac{FApT_0}{en}\right)}$$

It can be demonstrated, by means of a Fourier transformation, that $T_0/n = 1/(2f)$; hence we may write

$$N = \sqrt{\left(\frac{FAp}{2ef}\right)}$$

Actually, the picture/noise ratio should have been written

$$N = \sqrt{\left(\frac{FAp}{2ef(1 + k'')}\right)}$$

where the factor k'' takes into consideration the fluctuations in the entire group of multiplied photo-electrons which strike the mosaic and induce " noise " directly on the signal plate. The value of k'' depends on a great many variables. Its value cannot be less than unity, and for the purpose of calculation will be assumed to be in the neighbourhood of 10.

On this basis, the limiting amount of light which will produce a picture signal equivalent to 10 times the r.m.s. noise will be

$$\begin{aligned} F &= \frac{2ef(1 + k'')N^2}{Ap} \\ &= 7 \times 10^{-7} \text{ lumen per cm}^2 \quad . \quad . \quad (9) \end{aligned}$$

For the case just considered it would require an image multiplication of 500–1 000 to reach the limiting sensitivity. It is interesting to note that this limit is of about the same order of magnitude as for the case of the low-capacitance iconoscope. In general, it is possible to show that the limiting light sufficient to give a picture/noise ratio of N for an ideal storage television system (where the conversion efficiency is 100 %) will be

$$F = \frac{2efN^2}{Ap} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

While experimental tubes have been made with more than one stage of image multiplication, this technique has not been developed to a sufficient extent to be applicable to a commercial iconoscope in use in the television field test.

Very successful single-stage image-multiplier iconoscopes have been built. Fig. 10 shows diagrammatically such a tube. It consists, essentially, of an electron image tube* which projects on to a secondary-emissive mosaic an electron reproduction of an optical image formed on the photocathode. The mosaic in this instance differs from that in the standard iconoscope in that the mosaic elements extend through the insulating matrix in such a way that the electron image can be formed on one side while the mosaic is scanned on the other. If the mosaic is scanned while the photocathode is in darkness, the potential of each element will be nearly the same as that of the second anode, owing to the action of the beam and the redistribution of electrons.

When light is projected on to the photocathode, electrons will be emitted. These electrons are accelerated by the electron optical system and refocused on the mosaic. Each element thus bombarded will emit secondary electrons which will be drawn to the anode cylinder, since the latter is at a positive potential with respect to the mosaic. If the secondary-emission ratio of an element is, for example, B, the net current to it will be $(B - 1)$ times the primary current incident upon it. It should be pointed out, however, that the average amplification of the mosaic will not be $(B - 1)$, owing to the fact that the elements do not cover the entire surface under the electron image. If c be the fraction of the surface covered by the elements, then the effective gain will be $c(B - 1)$.

The electron optical part of this iconoscope is identical with the electron image tube, for which purpose the latter was developed. It consists of a semi-transparent photocathode; a cathode cylinder composed of five rings, each at a successively higher positive potential; and an anode cylinder which is maintained at approximately 1 000 volts positive. The lens of this system may be regarded as being located between the cathode and the anode cylinder, though actually it is a thick lens occupying a considerable portion of the total length of the system. The magnification of such a system can be shown* to be $m = v/(2u)$, where u and v respectively are the object and image distances from the lens. For the type of tube illustrated, where unity magnification of the image is used, the length of the cathode cylinder is half that of the anode cylinder.

The cathode is curved, with a radius equal to the lens diameter. This curvature not only corrects for image distortion and for curvature of the image field but also reduces the astigmatism to such an extent that it no longer limits the resolution in any part of the field.

The semi-transparent photo-electric surface used is caesium on oxidized silver. It is formed by evaporating a thin layer of silver on to the cathode disc from a filament located directly behind the aperture forming the electron lens. This silver is then oxidized by means of an electric discharge in oxygen at a low pressure, until the layer becomes almost completely transparent. Caesium is admitted, and the tube is baked exactly as is done in activation of a photo-electric cell. As a final step, additional silver is evaporated on to the surface and the tube is again baked. This final silver sensitization not only increases the photosensitivity and conductivity of the film, but also adds to its stability. This type of surface will have a photo-sensitivity of 20 to 25 microamp. per lumen, and a colour response very similar to that of a caesium photocell.

The most difficult item in the image-multiplier iconoscope to construct is the mosaic. One method by which a suitable mosaic can be built is as follows: A fine-mesh, electrodeposited nickel screen forms the base. It is coated with a thin layer of special vitreous enamel in such a way that its entire surface is completely insulated. The interstices in the screen are then filled with silver oxide made into a paste with an appropriate binder. The screen is finally heated to a temperature just under the melting point of the enamel in order to drive off the binder and to reduce the silver oxide to metallic silver. The arrangement of the elements and the actual construction of this type of tube will be clear from Fig. 10.

Actual tests on this type of iconoscope show that its sensitivity is about 10 times greater than that of a standard iconoscope. This added sensitivity is due, in part, to the secondary-emission multiplication and, in part, to the greater photosensitivity of the light-sensitive surface. For the present, this type of tube must be regarded as a purely experimental device because of the difficulties of producing commercially screens free from blemishes, due to irregular electrical leakage between the mosaic elements and the base screen. There is every reason to believe, however, that this type of tube can be made commercially available in the near future.

CONCLUSION

In conclusion, it may be said that the iconoscope has, in actual field test, proved itself to be a very practical pick-up device in spite of its low theoretical efficiency. The tube has been accepted as the sole pick-up equipment in several extensive television broadcast projects, both in the United States and abroad, and has been rapidly gaining general recognition. It would, nevertheless, be very desirable to increase the sensitivity of the iconoscope, and this paper describes several methods by which this may be accomplished. Before these principles can be incorporated in tubes to be used for broadcast purposes, a great deal of research and development work must be done. Eventually, however, it will be possible to produce a tube which will operate at even lower light levels than at present.

The work described has been possible only through the co-operation of the members of the research staffs of both the Victor and the Radiotron Divisions of the RCA Manufacturing Co. Particular mention should be made of the work of the late Mr. G. N. Ogloblinsky and that of Messrs. H. Iams and A. W. Vance, who have contributed so materially to the developments described in this paper.

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* See Reference (3).

† *Ibid.*, (4).

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(2) V. K. Zworykin, G. A. Morton, and L. Malter: "The Secondary Emission Multiplier—A New Electronic Device," *Proceedings of the Institute of Radio Engineers*, 1936, vol. 24, p. 351.

(3) G. A. Morton and E. G. Ramberg: "Electron Optics of an Image Tube," *Physics*, 1936, vol. 7, p. 451.

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PROCEEDINGS OF THE INSTITUTION

916TH ORDINARY MEETING, 21ST OCTOBER, 1937

Mr. H. T. Young, the retiring President, took the chair at 6 p.m.

The Chairman referred to the death of the Rt. Hon. Lord Rutherford of Nelson, O.M., F.R.S., Faraday Medallist in 1930, and asked the members present to rise in silence as a mark of their sympathy and regret.

The minutes of the Annual General Meeting held on the 6th May, 1937, and of the Ordinary Meeting held on the same day, were taken as read and were confirmed and signed.

A list of candidates for election and transfer, approved by the Council for ballot, was taken as read and was ordered to be suspended in the Hall.

The Chairman announced that during the period May to September 676 donations and subscriptions to the Benevolent Fund had been received, amounting to £536. A vote of thanks was accorded to the donors.

The Premiums (see vol. 80, page 677, and vol. 81, page 287) awarded for papers during the past session were presented by the chairman to such of the recipients as were present.

Mr. Young then vacated the chair, which was taken by the new President, **Sir George Lee, O.B.E., M.C.**, amid applause.

Dr. C. C. Paterson: Mr. H. T. Young, who has just left the presidential chair, has put The Institution greatly in his debt, for he has not spared himself in the service of The Institution, whether at our meetings here or in the provinces or as our chief representative at functions of other Institutions and bodies. I think that every man who is invited to this presidential chair, and is faced with what is indeed a very formidable task, seeks consolation by saying to himself " It is their fault, not mine, for choosing me; I will do my best, but it is their responsibility." Well, we were not afraid when we took the responsibility of inviting Mr. Young, and we have not been disappointed. He has shown ability and judgment in many difficult situations. He has made his catholic interest in all phases of electricity felt throughout the industry, and he and Mrs. Young have everywhere upheld our good name with dignity and with very great charm. He has indeed done his best, and we thank him, and we thank Mrs. Young also. It is, of course, always sad when the induction of a new President means that we have to escort another old and trusted friend from the presidential chair on to the shelf. The shelf is not at all a bad place and we welcome Mr. Young on to it, because we know that he will continue to give his very best gifts to the welfare of The Institution. And so, in the time-honoured formula of this Institution, I propose " That the best thanks of The Institution be accorded to Mr. H. T. Young for the very able manner in which he has filled the office of President during the past year."

Dr. A. P. M. Fleming: I should like to associate myself most fully with the sentiments that Dr. Paterson has expressed. The duties of a President are varied and manifold. Mr. Young came to the presidential chair as a very eminent member of a very important section of our industry, and he has fulfilled most ably every duty that his office has imposed upon him. I should like particularly to refer to those presidential duties that are, perhaps, not ordinarily appreciated by the general body of members, namely the work of the Council and of the many Committees which are necessary nowadays to carry out adequately the functions of The Institution. This work calls for much effort and takes up a great deal of time, and Mr. Young has been unremitting in his labours. Those of us who have had the privilege of working with him have appreciated the sound judgment and good leadership which he has always exercised, and his unfailing courtesy, tact, and geniality. We are greatly indebted to him, and he is deserving of our most grateful thanks. I have the greatest pleasure in seconding this resolution.

The resolution was then carried with acclamation.

Mr. H. T. Young: I should like first to thank Dr. Paterson and Dr. Fleming for their very kind and generous remarks, which I feel I do not really deserve, and also to thank all of you for the way in which you have received those remarks. For remarks of that kind to be made and to be received in so cordial a manner is, to any man who has endeavoured to put his best into a job, a very great stimulus to try to do more for The Institution and its members.

I passed through an apprenticeship of 6 years before I became President. First I had 3 years as an Ordinary Member of Council, and then 3 years as a Vice-President;

but until I took office as President I did not realize the high prestige associated with the presidential chair as a result of its having been occupied by so many eminent predecessors. I have been particularly proud to follow them and to represent this Institution in the diverse duties—many very enjoyable—which a President is called upon to perform. It was with a great deal of pride that I received the Royal Command to attend the Coronation ceremony in Westminster Abbey last May as the representative of this Institution. I am sure that the members in general recognized it as a special privilege accorded to us.

In conclusion, I should like to thank my colleagues on the Council, and particularly the vice-presidents, the chairmen of committees, and the chairmen of the Local Centres, for the able way in which they assisted me during my year of office. I wish also to thank the Secretary, Mr. Rowell, for the advice and assistance which he has given me whenever I have sought it, and for the very loyal and efficient work which has been done by the Assistant Secretaries and the other members of his staff during my year of office.

The President then delivered his Inaugural Address (see page 1).

Mr. F. Gill: In congratulating and thanking the President for his interesting Address, I want to go back a little more than 30 years and use the words which were employed by Mr. Swinburne (later Sir James Swinburne), then a Past-President, to a very great predecessor of Sir George Lee, Mr. Gavey (later Sir John Gavey). After the latter's Presidential Address, Mr. Swinburne said: "He has taught us to realize more thoroughly than we have done before that there may be an infinite amount of engineering in dealing with what are almost infinitesimally small things." I think that those words will not be unpleasing to our President.

I have been very much impressed by the references made in the Address to economy. Sir George wound up his Address by saying that he had essayed to talk about economy and quality blended together. I was also impressed by references to what I would call true cost, by which I do not mean economy in buying a vaguely-specified article for the lowest price at which it can be obtained, but I mean the least cost at which it is possible to possess, operate, and replace a very definitely specified set of requirements. In this case we have a research worker turning his gifts to this most important problem. In many growing organizations, and certainly in those of the public utility type, one of the major and very difficult problems is how to construct piecemeal, day by day, a thing which must be at all times a harmonious and economical whole. In doing that, the fundamental plan, which has been referred to by the President, is exceedingly important. It has two chapters: the first is the ascertainment, and the second the adoption, of the demand to be catered for.

I hope that copies of this Address will be sent to the engineering colleges, and that the authorities of those colleges will ask themselves the question "Are the young men who are now entering the engineering profession being taught how to evaluate least cost and how to apply it, with all the cautions that are necessary, to the selection of plant?"

It would be ungrateful on my part if I did not refer to the very kind remarks which Sir George has made about the efforts of the manufacturers to reduce costs. They have striven very earnestly along that line, but I think that the manufacturers would be very ready to say that a great deal of the credit is due to the Post Office for the manner in which they now place orders.

In conclusion I have to propose "That the best thanks of The Institution be accorded to Sir George Lee for his interesting and instructive Presidential Address, and that with his permission the Address be printed in the *Journal* of The Institution."

Sir Noel Ashbridge: It is not often that this Institution has the privilege of listening to an Address from one who occupies a position which is so important and, so far as this country is concerned, also unique. The position of engineer-in-chief of the Post Office is unique from several points of view. I remember hearing Sir George Lee mention some time ago in a discussion on industrial relations that he was responsible for a staff of some 30 000. It must be a formidable task to direct such a vast army of engineers, and there must be very intricate problems in directing a vast engineering organization which at the same time is a Government Department and a highly successful commercialized profit-making institution. Many of the problems which have arisen since the War have been due to what I might almost call the too rapid development of the science of communications generally. This must have added very greatly to the problems with which Sir George has so successfully contended.

The President in his Address has referred to the subject of co-operation, and I should like to take this opportunity of paying a high tribute to the co-operation which the B.B.C. has always received from Sir George Lee and his staff in all matters relating to the broadcasting service. He is also Chairman of the Radio Research Board and is responsible for organizing co-operative research on a large scale. There was a time, many years ago, when important research was carried out very largely by some gifted individual working with one or two assistants in a cellar or in the proverbial attic. I do not, of course, want to belittle the efforts of anyone who is still working in this way, but the present tendency—and I expect that it will be even greater in the future—is for important research to be carried out by co-operation between large organizations. In this work Sir George Lee has already rendered very great service.

You have already expressed your appreciation of this Address, but it is satisfactory to know that a far larger number will read it and appreciate it at their leisure. I hope that at any rate a reasonable proportion of these will be business men who are interested in efficient communication. In conclusion, I have very great pleasure in seconding the vote of thanks proposed by Mr. Gill.

The vote of thanks was then carried with acclamation and, after the President had briefly replied, the meeting terminated.

INSTITUTION NOTES

JOINT MEETING OF KINDRED SOCIETIES, 1ST MARCH, 1938

The Council have accepted an invitation from The Institution of Automobile Engineers for the I.E.E. to participate in a Joint Meeting of Kindred Societies to be held on Tuesday, 1st March, 1938, when the following papers on the subject of "Essential Road Conditions Covering the Safety of Modern Traffic" will be read and discussed:—

"Road Planning," by Dr. T. Adams.

"Road Construction," by Mr. C. Howard Humphreys.

"Road Illumination," by Messrs. L. J. Davies and G. S. Lucas.

The meeting will be held in the Great Hall of The Institution of Civil Engineers, Great George Street, Westminster, S.W.1, at 7 p.m. (Light refreshments 8.15 p.m. to 8.45 p.m.)

A limited supply of advance copies of the papers to be read will be available about one week before the meeting, and members desiring to receive copies should apply to the Secretary of the I.E.E., Savoy Place, London, W.C.2.

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E. Ridley, M.B.E.
P. L. Rivière.
J. F. Stanley, B.Sc.(Eng.).

And	*Representing*
L. Pyke	Association of Consulting Engineers.
A. Kirk	Association of Supervising Electrical Engineers.
E. B. Wedmore	British Electrical and Allied Industries Research Association.
C. A. Martin	British Electrical and Allied Manufacturers' Association.
C. Rodgers, O.B.E., B.Sc., B.Eng.	
T. M. H. Stubbs	
J. B. Tucker	
A. J. L. Whittenham	
W. F. Bishop	Cable Makers' Association.
S. W. Melsom	
G. F. A. Norman	Electrical Contractors' Association.
E. A. Reynolds, M.A.	

And	*Representing*
R. A. Ure	Electrical Contractors' Association of Scotland.
J. Howard-Blood E. B. Hunter W. H. Tuckey	Fire Offices Committee.
H. W. Swann	Home Office.
R. W. L. Phillips J. W. J. Townley	Incorporated Municipal Electrical Association.
E. W. Farr	Independent Cable Makers' Association.

REPRESENTATIVES OF THE INSTITUTION ON OTHER BODIES

The following is a list of representatives of The Institution on other bodies, and gives the dates on which they were appointed:—

Admiralty:

Selection Committee for Vacancies for Assistant Electrical Engineers:

R. T. Smith (1 July, 1937).

Bristol University:

H. F. Proctor (8 Jan., 1925).

British Cast Iron Research Association:

E. B. Wedmore (25 Sept., 1924).

British Electrical and Allied Industries Research Association:

Council:

J. M. Donaldson, M.C. (18 Dec., 1930).
C. P. Sparks, C.B.E. (18 Dec., 1930).

Sub-Committee on Connections to Large Gas-filled Lamps:

C. C. Paterson, O.B.E., D.Sc. (24 Oct., 1929).
B. Welbourn (24 Oct., 1929).

Sub-Committee on Earthing and Earth Plates:

S. W. Melsom (31 Jan., 1930).

British Electrical Development Association: Committee on Rural and Agricultural Electrification:

J. M. Donaldson, M.C. (20 Oct., 1927).
R. Grierson (20 Oct., 1927).

British Standards Institution:

Engineering Divisional Council:

P. V. Hunter, C.B.E. (11 April, 1935).
Sir George Lee, O.B.E., M.C. (22 April, 1937).
W. B. Woodhouse (19 March, 1936).

Electrical Industry Committee:

Lt.-Col. K. Edgcumbe, T.D. (5 March, 1925).
F. Gill, O.B.E. (21 May, 1914).
J. S. Highfield (21 May, 1914).
E. H. Shaughnessy, O.B.E. (23 March, 1933).
R. T. Smith (21 May, 1914).

Technical Committee on Electric Clocks:

E. B. Hunter (5 Dec., 1935).

Technical Committee on Electric Power Cables:

S. W. Melsom (10 Jan., 1930).

British Standards Institution—*continued.*

Technical Committee on Electric Signs:

L. Barlow (14 May, 1931).
R. W. L. Phillips (17 Feb., 1932).

Technical Committee on Electrical Accessories:

H. J. Cash (31 March, 1925).
F. W. Purse (31 March, 1925).

Technical Committee on Electrical Instruments:

Lt.-Col. K. Edgcumbe, T.D. (15 Feb., 1923).

Technical Committee on Electrical Nomenclature and Symbols:

C. C. Paterson, O.B.E., D.Sc. (8 Jan., 1920).

Technical Committee on Electricity Meters:

A. J. Gibbons, B.Sc.Tech. (28 March, 1930).
O. Howarth (22 Oct., 1936).
G. F. Shotter (28 Feb., 1929).

Technical Committee on Identification of Pipe-lines in Buildings:

R. Grierson (11 May, 1933).

Technical Committee on Lifts, Hoists, and Escalators:

H. Marryat (25 Oct., 1934).

Technical Committee on Overhead Transmission Lines Material:

J. L. Eve (11 Nov., 1936).

Technical Committee on Regulations for Overhead Lines:

W. Fennell (23 April, 1936).
S. R. Siviour (23 April, 1936).

Technical Committee on Safety Requirements:

H. J. Cash (22 Oct., 1936).
R. W. L. Phillips (22 Oct., 1936).
E. Ridley, M.B.E. (11 Feb., 1937).

Technical Committee on Testing and Expressing the Overall Performance of Radio Receivers:

R. P. G. Denman, M.A. (21 Oct., 1937).

Technical Committee on Under-Floor Duct Systems:

E. B. Hunter (22 Oct., 1936).
H. W. Swann (22 Oct., 1936).

Technical Committee on Wireless Apparatus and Components:

E. H. Shaughnessy, O.B.E. (30 Sept., 1925).

Sub-Committee on Automatic Change-Over Switches for Emergency Lighting Systems:

E. Ridley, M.B.E. (22 Oct., 1936).

Sub-Committee on Ceiling Roses:

H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

Sub-Committee on Conduit Fittings:

H. J. Cash (18 May, 1927).

Sub-Committee on Connectors for Portable Appliances:

H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 Mar., 1937).

British Standards Institution—*continued.*

Sub-Committee on Connectors for Radio Apparatus:
R. W. L. Phillips (6 Jan., 1931).

Sub-Committee on Copper Conduit Tubes (Light Gauge):
H. Marryat (17 Dec., 1936).

Sub-Committee on Cut-outs for Radio Receivers:
S. W. Melsom (5 Dec., 1935).

Sub-Committee on Distribution Boards:
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).

Sub-Committee on Instrument Transformers:
G. F. Shotter (22 Feb., 1934).

Sub-Committee on Lead Alloys for Cable Sheathing:
B. Welbourn (22 June, 1933).

Sub-Committee on Letter Symbols:
A. T. Dover (21 Nov., 1929).

Sub-Committee on Light-Gauge Copper Tubes for Electrical Conduits:
H. Marryat (17 Dec., 1936).

Sub-Committee on Low-Voltage Cut-outs:
H. J. Cash (22 June, 1926).
E. B. Hunter (25 Feb., 1927).
S. W. Melsom (25 Feb., 1927).

Sub-Committee on Low-Voltage Transformers for Lighting Equipment and Bell-Ringing Circuits:
G. F. A. Norman (11 Feb., 1937).

Sub-Committee on Mains Supply Apparatus for Radio Receivers, etc.:
R. W. L. Phillips (11 Dec., 1930).
F. W. Purse (16 Oct., 1928).

Sub-Committee on Non-Ignitable and Self-Extinguishing Boards for Electrical Purposes:
S. W. Melsom (24 Oct., 1935).
E. Ridley, M.B.E. (24 Oct., 1935).

Sub-Committee on Protected-type Plugs and Sockets:
H. J. Cash (26 Oct., 1932).
F. W. Purse (26 Oct., 1932).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Radio Interference from Trolley-Buses and Tramcars:
C. C. Paterson, O.B.E., D.Sc. (7 Nov., 1935).

Sub-Committee on Radio Nomenclature and Symbols:
Col. A. S. Angwin, D.S.O., M.C., B.Sc.(Eng.) (7 April, 1932).

Sub-Committee on Telephone and Radio Connectors:
R. W. L. Phillips (28 Feb., 1935).
A. J. L. Whittenham (28 Feb., 1935).

Sub-Committee on Tumbler Switches:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).

British Standards Institution—*continued.*

Sub-Committee on Wall-plugs and Sockets:
H. J. Cash (23 Jan., 1924).
F. W. Purse (23 Jan., 1924).
J. W. J. Townley (11 Mar., 1937).

Sub-Committee on Welding Plant and Equipment:
Major J. Caldwell, J.P. (26 Oct., 1933).

Panel on Graphical Symbols for Interior Installations:
G. F. A. Norman (11 Feb., 1937).
E. Ridley, M.B.E. (11 Feb., 1937).

Colliery Requisites Industry Committee:
C. T. Allan (3 July, 1924).

Technical Committee on Mining Electrical Plant:
A. C. Sparks (27 March, 1930).

Birmingham Regional Committee:
F. C. Hall.

Glasgow Regional Committee:
F. Anslow.

Manchester Regional Committee:
W. T. Anderson.

Newcastle Regional Committee:
S. A. Simon, B.A.

Sheffield Regional Committee:
M. Wadeson.

Technical Committee on Coal:
W. M. Selvey (19 Jan., 1928).

Technical Committee on Engine Testing Fittings:
W. M. Selvey (22 Oct., 1931).

Technical Committee on Engineering Symbols and Abbreviations:
A. T. Dover (21 Nov., 1929).

Technical Committee on Fans:
Prof. R. O. Kapp, B.Sc. (22 Oct., 1931).

Technical Committee on Land Boilers:
W. E. Highfield (2 July, 1931).
W. M. Selvey (7 April, 1932).

Technical Committee on Larch Poles:
B. Welbourn (21 Jan., 1932).

Technical Committee on Lightning Conductors:
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (30 Jan., 1936).

Technical Committee on Methods of Test for Dust Extraction Plant:
C. L. Blackburn, B.A. (25 Oct., 1934).

Technical Committee on Pipe Flanges:
W. M. Selvey (14 April, 1921).

Technical Committee on Pump Tests:
R. S. Allen (2 July, 1931).

British Standards Institution—*continued.*

Technical Committee on Railway Signalling Apparatus:
A. F. Bound (24 Oct., 1929).

Technical Committee on Rating of Rivers:
G. K. Paton (20 Oct., 1927).

Technical Committee on Rubber Belting:
C. Rodgers, O.B.E., B.Sc., B.Eng. (5 Jan., 1928).

Technical Committee on Traction Poles:
T. L. Horn (4 Feb., 1926).

Sub-Committee on Accessories for Land Boilers:
W. M. Selvey (7 April, 1932).

Sub-Committee on Boiler and Superheater Tubes:
W. M. Selvey (7 April, 1932).

Sub-Committee on Fittings for Land Boilers:
W. M. Selvey (7 April, 1932).

Sub-Committee on Water-Tube Boilers:
W. E. Highfield (2 July, 1931).
W. M. Selvey (7 April, 1932).

Sub-Committee on Portable Railway Track:
R. T. Smith (25 Oct., 1928).

Illumination Industry Committee:
Lt.-Col. K. Edgcumbe, T.D. (28 Feb., 1924).
P. Good (28 Feb., 1924).
H. W. Gregory (26 Oct., 1933).
Prof. J. T. MacGregor-Morris (28 Feb., 1924).
J. W. J. Townley (16 May, 1935).

Building Industry, National Council for: Advisory Committee on Building Acts and Bye-laws:
F. W. Purse (20 Oct., 1932).
H. T. Young (20 Oct., 1932).

City and Guilds of London Institute:

Advisory Committee on Electrical Engineering Practice:
Prof. E. W. Marchant, D.Sc. (22 June, 1933).

Advisory Committee on Electrical Installation Work:
Prof. S. Parker Smith, D.Sc. (20 Oct., 1927).

Advisory Committee on Illuminating Engineering Examinations:
C. C. Paterson, O.B.E., D.Sc. (8 April, 1937).

Advisory Committee on Telecommunications:
E. H. Shaughnessy, O.B.E. (22 Oct., 1931).

Fellowship Committee:
W. H. Eccles, D.Sc., F.R.S. (19 April, 1928).

Council for the Preservation of Rural England:
J. M. Kennedy, O.B.E. (10 Jan., 1929).

Electrical Association for Women:

Council:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (18 Dec., 1924).

Committee for Training of Women Demonstrators:
J. R. Beard, M.Sc. (4 Nov., 1937).

Engineering Joint Council:
P. V. Hunter, C.B.E. (8 March, 1934).
J. M. Kennedy, O.B.E. (20 Feb., 1936).

Sub-Committee to Consider Overseas Co-operation:
F. Gill, O.B.E. (1 July, 1937).

Engineering Public Relations Committee:
J. M. Kennedy, O.B.E. (6 May, 1937).

Imperial College of Science and Technology: Governing Body:
W. M. Mordey (12 April, 1923).

Imperial Minerals Resources Bureau Conference Copper Committee:
B. Welbourn (18 Sept., 1919).

Institute of Industrial Administration: Examinations Advisory Council:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Oct., 1934).

Institute of Metals: Corrosion Research Committee:
W. M. Selvey (19 July, 1923).

Institution of Civil Engineers:

Engine and Boiler Testing Committee:
C. P. Sparks, C.B.E. (19 Oct., 1922).

Earthing to Water Mains Sub-Committee:
Ll. B. Atkinson (20 Feb., 1936).
P. Dunsheath, O.B.E., M.A., D.Sc. (20 Feb., 1936).
F. W. Purse (20 Feb., 1936).
P. J. Ridd (20 Feb., 1936).

International Association for Testing Materials:
J. M. Kennedy, O.B.E. (5 July, 1928).

International Engineering Congress, Glasgow, 1938:

General Committee:
H. C. Babb (8 April, 1937).
J. Miller (8 April, 1937).
R. B. Mitchell (8 April, 1937).
P. F. Rowell (*ex officio*) (8 April, 1937).

London Committee:
J. R. Beard, M.Sc. (6 May, 1937).
P. F. Rowell (*ex officio*) (6 May, 1937).

Glasgow Committee:
J. Miller (13 April, 1937).
P. F. Rowell (*ex officio*) (13 April, 1937).

International Illumination Commission: British National Committee:
Lt.-Col. K. Edgcumbe, T.D. (27 Nov., 1913).
P. Good (18 Sept., 1919).
H. W. Gregory (26 Oct., 1933).
Prof. J. T. MacGregor-Morris (27 Nov., 1913).
J. W. J. Townley (16 May, 1935).

Joint Committee on Materials and their Testing:
P. Good (25 Feb., 1937).

Joint Fuel Committee:
C. P. Sparks, C.B.E. (7 Jan., 1932).

Loughborough Technical College: Advisory Committee:
Ll. B. Atkinson (11 April, 1929).

Metalliferous Mining (Cornwall) School: Governing Body:
L. A. Hards (1 Dec., 1927).

National Physical Laboratory: General Board:
J. M. Donaldson, M.C. (7 Nov., 1935).
C. C. Paterson, O.B.E., D.Sc. (3 Nov., 1932).

National Register of Electrical Installation Contractors:
H. J. Cash (12 March, 1931).
P. V. Hunter, C.B.E. (18 Feb., 1926).
W. R. Rawlings (18 Feb., 1926).
W. M. Selvey (18 Feb., 1926).

National Smoke Abatement Society:
H. C. Lamb (26 Oct., 1933).
C. D. Taite (26 Oct., 1933).

Professional Classes Aid Council:
P. F. Rowell (20 April, 1928).

Royal Engineer Board:
W. B. Woodhouse (19 March, 1925).

Royal Society:

National Committee on Physics:
Prof. W. M. Thornton, O.B.E., D.Sc., D.Eng. (19 Nov., 1936).

National Committee for Scientific Radio:
Prof. C. L. Fortescue, O.B.E., M.A. (19 Nov., 1936).
E. H. Rayner, M.A., Sc.D. (9 Nov., 1933).

Science Museum, South Kensington: Advisory Council:
C. C. Paterson, O.B.E., D.Sc. (1 July, 1937).

Town Planning Institute: Committee on Overhead Transmission Lines:
J. M. Kennedy, O.B.E. (7 April, 1932).

Union of Lancashire and Cheshire Institutes (Panel for Engineering):
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (28 Feb., 1924).
Prof. Miles Walker, M.A., D.Sc., F.R.S. (28 Feb., 1924).

University College, Nottingham: Electrical Engineering Advisory Committee:
A. D. Phillips (23 Feb., 1933).

War Office Mechanization Board:
W. H. Eccles, D.Sc., F.R.S. (19 Jan., 1928).

Women's Engineering Society:
A. P. M. Fleming, C.B.E., D.Eng., M.Sc. (25 Sept., 1924).

World Power Conference (British National Committee):
R. T. Smith (1 May, 1930).

ELECTIONS AND TRANSFERS

At the Ordinary Meeting of The Institution held on the 4th November, 1937, the following elections and transfers were effected:—

Elections

Members

Eckersley, Thomas Lydwell, B.A., B.Sc.
Werren, Herbert Trowbridge.

Associate Members

Allison, Alfred John.
Atkinson, William.
Bezjian, Mihran Z., M.Sc. (Eng.).
Birch, Sidney.
Blackman, Ronald Arthur.
Brighten, Henry William.
Brown, Archibald Hoy.
Brown, William Arthur.
Clifford, Cecil Frank, B.Sc.
Dennison, Richard Thomas A.
Drewe, Eric Charles.
Evens, Harold Walter.
Fee, Donald John.
Griffith, Charlie.
Hammersley, Albert Ernest.
Harmston, Alexander Thevenot.
Heath, Arthur Alexander, M.A.
Holbrook, Charles James.
Holt, Donald, B.Sc.Tech.
Jeffrey, Charles.
Jones, Philip, Squadron Leader.
Maxted, Robert, B.E.
Morgan, Jasper Ralph H. B.E.
Mundel, Ernst Hermann E., Dr.Ing.
Nimmo, Adam Arthur.
Randall, Walter Frederick, B.Sc.
Robinson, Rowland Plant.
Sadleir, Keith Arthur L.
Seaman, Matthew, M.Sc. Tech.
Singer, Alexander, Dipl. Ing.
Tomlinson, Harry Thomas.
Townsend, Eric Henry.
Wickham, Evelyn Twysden, Capt., R.N.(Ret.).
Wood, Peard Thornton.

Associates

Anderson, Edward Arthur.
Bandara, Albert Victor S.
Blagg, Sydney Moody.
Blofeld, Thomas Guest.
Bruce, Francis Charles.
Davies, William.
Day, Ernest William C.
Gardiner, John Henry.
Gill, Leonard Payne.
Jadeja, Kumar Kesarisinhji R.
Morinan, Leonard Percy.
Mottram, Harry F.
Wilson, Hubert George A.

Graduates

Acons, Eric Herbert.
Adams, William Arthur.
Anderson, William Harley.
Arkinstall, Lichfield.
Bamford, William Donald.
Booth, Francis William L.
Boud, Frederick Harry.
Brown, Kenneth Stanley, B.E.
Capeling, Leslie Frank.
Cemali, Ali Kemal, B.Sc. (Eng.).
Chadwick, Allen.
Coombes, Alan George.
Datta, Sudhindra Chandra.
Duff, John Thomas.
Ewen, Alfred Whitelaw.
Gifford, Ansell Wandless.
Goudge, Kenneth Alfred, B.A.
Grais, Hanna, M.A., B.Sc.
Hall, Charles Henry.
Hawkes, Richard Christian, B.Sc.(Eng.).
Hughes, William Edward, B.Eng.
Ingham, Leslie.
Ives, William.
Kacs, Benjamin.
Kebbell, Edward Rhodes.
Koo, Shu-Koh, B.Sc.
Kowshik, Dinkar Narsing, B.Sc.Tech.
Lee, Haumo, B.Sc.(Eng.).

Graduates—continued.

Lester, Guy Cyril O.
Lewis, Eurwyn, B.Sc.
McIntyre, John Alexander, B.Sc.(Eng.).
Makin, Thomas.
Meacock, John Arthur.
Mears, Robert James.
Nield, Cyril.
Parnell, Albert John.
Parsons, Arthur James.
Partington, Eric Victor.
Patrick, Ernest.
Pine, Angus Floyde.
Purohit, Madhav Dattatray.
Rama Rao, Gooty Tulsi.
Rickett, Donald Harry, B.Sc.(Eng.).
Robson, Lawrence Fendick, B.A.
Rosenfelder, Robert Isaac.
Smith, Dennis.
Surgenor, Fred Ingram.
Tankard, Clement Bolton.
Titley, Cresswell Oliver.
Tommins, Albert.
Towill, Sydney.
Underwood, Leonard Edwin.
Wait, David William.
Walker, George Edward.
Widdowson, William Frederick.
Winter, Charles William R.
Yorke, Roy.

Students

Agarwala, Gyan Prakash.
Aiyar, Suryanarayana Srinivasa.
Alexander, Hector James.
Allan, Alexander Frederick G.
Ambrose, Dermot Min.
Bagshaw, Arthur Sidney.
Bajaj, Gian Chand.
Balkrishnan, Narayan Iyer.
Bastian, Frederick Charles.
Bell, Robert Herbert.
Berge, Morris.
Bhatnagar, Sharda Bhushan.
Bower, Leonard Wilson.
Bowker, George Dickinson.
Bullock, Victor Bradshaw.
Bury, Gordon James.
Busby, Albert William.
Cawson, Roland George M.
Chubb, William Bernard.
Churchill, John Henry C.
Coates, Jack.
Collins, John Henry.
Combs, Charles Thomson.
Cooper, Ronald.
Cottrell, Seymour.
Cowley, Percy Edward A.
Crowe, Eric.
Cullum, Leslie Roy.
de Fonseka, Dudley Ransford H.
Desai, Maganlal Deoshanker.
Dick, Arthur John C.
Dotivala, Hormuz Dadabhai.
Dracup, Arthur.
Dubash, Dinshah Darabshaw.
Easton, Hone Iveson.
Eckett, Sidney Wallace.
Falconar, Edwin Martin.
Florida, Charles David.
Forster, Peter Charles T.
Francis, William David.
Freeland, Alan Stewart.
Galea, Fredrick Robert.
Galloway, John Arthur.
Gandhi, Manilal Jayakrishnadas.
Garner, Francis Charles.
Gates, Norman Percival.
Gee, Sydney Arthur.
George, Norman Jack.
Gibson, Albert James.
Goy, Charles Wilfred.
Greenall, John.
Griffith, Glyn David H.
Griffith, William Henry D.
Halliday, Kenneth William J.
Hampton, Denis Allen.
Haque, Abul Kasem F.
Hansford, Elsie Florence (Miss).
Hart, Edwin Samuel.
Hazell, Jack Richard.
Hill, William Percy.
Hilyer, Frederick Gordon.
Hobday, Stephen William.
Hogsett, Desmond Trimble.
Horner, George Henry.
Hoskin, William John.
Howard, Robert William.
Huckell, Noel Raymond.
Hurley, John Joseph.
Hutchinson, Geoffrey Pickworth.
Hynes, Ernest William R.
Isaac, John Edward.
Jackson, Gerald Breck.
Jadeja, Jilubha Mamubha.
James, John Douglas W.
Jarvis, John Ernest.
Jenkins, William Ernest A.
Jones, Norman.
Kabraji, Rustom Zal.
Kamal, Borhan.
Keele, Brian Rushworth.
Khan, Nisar Ahmad.
Kissel, John Frederick G.
Knowles, John.
Lake, Arthur Lawrence.
Lieberman, Lionel.
Liebers-Velthuisen, Johann Paul.
Logan, James.
McArthur, Roy Frederick.
McGhee, Joseph, Ph.D.
Machhina, Shavukshaw Dinshaw.
Maguire, Owen George.
Mahatme, Prabhaker Bhaskker.
Mahimtura, Harichand Narandas.
Marathe, Kashinath.
Mathiesen, Eric.
Mehta, Ragbir Singh.
Melville, Denis Hill.
Membry, Eric John.
Menty, Burjor Manchersha.
Millard, Harold Wilfred.
Mills, Eastall.
Mogford, Cecil John H.
Moore, Geoffrey Jack.
Munro, Hugh Alexander.
Muthalaly, K. N. A.
Natekar, Vinayak Narayan.
Neate, Roy Fredrick L.
Nentsky, Michael Ronald P.
Norwood, Harold.
Parakh, Adi Kaikhusru.
Parkhurst, John Wyndham E.
Pattison, John Charles.
Peacock, Roy Stewart.
Percival, Allan Edward.
Pereira, Charles Anthony F.
Phillips, Alban William.
Rao, A. Narasinga.
Rao, Guthikonda Virabhadra.
Rao, Vepa Venkata L.
Reynolds, Ronald Arthur.
Richardson, William Eric.
Rickland, Martin.
Robertson, Donald Graham.
Sastri, Dorbala Viswanatha.
Sawhney, J. S.
Scott-Lindsley, Mervyn Ewart.
Seervai, Homi Pirojshaw.
Seethapathirao, Devaguptapu.
Shah, Irshad Ali.
Shah, Nagindas Vithaldas.
Shah, Shantilal Amarchand.
Shankaran, Alladi.
Sheffield, Peter Conway.
Shepherd, Herbert Norman.
Shute, Guy Fleming.
Sneath, Wilfrid Samuel G.
Sores, Gaspar.
Squires, Mordecai.
Steele, Harry Theodore.
Stephenson, Thomas George.
Story, Charles Walter R.
Telfer, Henry.
Townsley, Jack Mallinson.
Trevorrow, Thomas William.
Vaughn, William Griffith J.
Wagle, Moreshwar Mangesh.
Webb, Albert.
Webb, Francis Leonard.
West, Kenneth.
Wilson, Richard William.
Woods, John Victor.
Young, George Sydney.

Transfers

Associate Member to Member

Arnett, Charles Thomas S.
Bostel, Alfred Charles.
Forster, Alfred Lindsay.
Harley, Laurence Shepheard, B.Sc.
Heath, Robert.
Matthews, Leonard John.
Menon, K. P. P., B.A., B.Sc.
Mirk, David Blair, B.Sc.
Parry, William, M.Eng.
Reading, John, B.Sc.(Eng.).
Richards, Samuel Hope.
Robertson, Cyril Ernest, Captain.
Rushton, Albert, M.Sc.
Salmon, John Bertram.
Spark, Joseph Duncan.
Steele, Robert Mansel.
Stevenson, James Ross.
Stevenson, Percy Ross.
Sutherland, John George A.

Associate to Associate Member

Barrell, Frank.
Evans, Herbert Martin.
Johnstone-Hall, Frederick Colin, Major, M.B.E.
Simpson, George Francis.

Graduate to Associate Member

Allerston, Pinder.
Andrews, Frederick Oswald, B.Sc.(Eng.).
Ashton, Edgar George, Ph.D.
Athalye, Dattatray Ganesh, B.A., B.Sc.
Bamford, William, B.Sc.(Eng.).
Barrett, Arthur Edwin, M.A.
Barrington, Reginald Jack C.
Batchelor, Ernest Lawrence.
Bevan, Percy Archibald T.
Blomfield, Frederick William R.
Brewer, Arthur Ernest, B.Sc.
Brown, Henry Robert.
Brown, William Edward.
Brunner, Henry Theodore, Lieut., R.A.O.C.
Butcher, Derek St. Aubyn.
Campbell, William Harold.
Collins, William Henry A.
Connor, Raymond Arthur W.
Copsey, Thomas.
Craig, Donald Hugh C.
Daines, Sidney Arthur.
Drake, William Edward J.
Dugdale-Bradley, John Oliver.
Egerton, Robert Charles.
Evans, Emlyn Rees, B.Sc.
Evans, Roderic Mervyn L., B.A.
Faithfull, Edgar Wilfred.
Freeman, Geoffrey Albert.
Gallop, John Winston, B.Sc.(Eng.).
Gambold, Thomas Howard.
Gartside, Arnold.
Goodman, Charles.
Green, Robert James P., B.Sc.
Haskard, John Leslie.
Hewitt, Thomas Herdman.
Hext, Frederick Maurice.
Hobbs, Norman David.
Hughes, Alfred George.
Hughes, Frederick Kingsley, B.Sc.(Eng.).
Johnson, Frederick William, B.Sc., Ph.D.
Kashyap, Hariwansh Lal, B.A., B.Sc.
Kerse, William Harold.
Lamb, Herbert Allan.
Langley, Arthur Henry, B.Eng., Ph.D.
Litton, Anthony Joseph, B.E., B.Sc.
McKenzie, Duncan Buchanan, B.Sc.
Manton, William Joseph W.
Marsden, Wilfrid Kenneth.
Martin, Donald Eustace.
Martin, William Wilson, B.Sc.(Eng.).
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Student to Associate

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ACCESSIONS TO THE REFERENCE LIBRARY

[NOTE.—The books cannot be purchased at The Institution; the names of the publishers and the prices are included only for the information of members. (*) denotes that the book is also in the Lending Library.]

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